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ABSTRACT

This annotated bibliography has been compiled as a guide for the researcher of swimming in referring to experimental studies in the physiological, mechanical, psychological, and medical aspects of swimming. The studies have been briefly annotated to enable the reader to quickly determine the salient points the authors made in their studies. The organization of the material is listed alphabetically according to author under four categories: physiological, mechanical, psychological, and medical aspects of swimming. (JD)

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An Annotated Bibliography of Experimental Research Concerning Competitive Swimming

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Macalester College

St. Paul, Minnesota

1985

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Preface

This annotated bibliography has been compiled as a guide for the researcher of swimming in referring to experimental studies in the physiological, mechanical, psychological, and medical aspects of swimming. The studies have been briefly annotated to enable the reader to quickly determine the salient points the authors made in their studies.

The organization of the material is listed alphabetically according to author under four catagories; physiological, mechanical, psychological and medical aspects of swimming.

Physiological Aspects

Adams, B., Grobech, C. E., & Moran, E. (1984). Endurance through adjusted ph. Swimming Technique, 21, 3, 15-18.

This study hypothesized that in the anaerobic state a rise in the ph (alkalosis) would delay the lowering of ph below normal and therefore delay the onset of fatigue and facilitate endurance and that an alkaline ash diet would bring about this change. Ten male collegiate swimmers were tested for endurance. Prior to this ten minute swim they were analyzed for systemic ph. Diet was rotated weekly. The mean systemic ph following 3 days of alkaline-ash differed significantly from those on normal diet. An increase in ph of the body following the alkaline ash diet was found.

Adee, D. D. (1953). Effect of environmental temperature on heart rate, deep body temperature and performance in swimming. Unpublished doctoral dissertation, University of Minnesota.

This study was to determine the effects of varying water temperatures on swimming performance. Seven college trained swimmers were tested in speed and endurance swims over an 8 wk. period. Pool temperatures varied from 64-94 degrees F. inclusive. Testing included a 50 yd. sprint, a 20 min. swim, measurements of pulse rate, body temp. and performance times. No difference were found in recovery pulse after swimming 50 yd. in water from 64-94 degrees F., but it did increase significantly with increasing temperature after both 20 min. paced and competitive 1500 m. swims. Rectal temperatures increased significantly with increasing water temperature. A .05 degree was the average increase for every degree increase in pool temperature in swims beyond the fifty yd. dash. It increased to better than .10 degree F. for the other swims. Best performance times were done when the rectal temperature was about 101 degrees F.

Adrian, M., Mohan, S., & Karpovich, P. V. (1966). Energy cost of leg kick, arm stroke, and whole crawl stroke. Journal of Applied Physiology, 21, 1763-1766.

The net energy costs of the leg kick, arm stroke, and whole stroke of the crawl were determined and formulas for the calculation of oxygen derived. Results showed that for a given speed, energy cost of the leg kick was 2 to 4 times greater than the arm stroke and whole stroke which substantiates opinions of swim coaches that in long-distance crawl swimming the leg action should be reduced to a minimum.

Ainsworth, J. L. (1970). The effect of isometric-resistive exercises with the exer-genie on strength and speed in swimming. Unpublished doctoral dissertation, University of Arkansas.

This study was to determine the effectiveness of isometric-

resistive exercises on strength and speed in swimming and to determine the effectiveness of isometric-resistive exercises with the exer-genie on strength as measured by arm flexion and knee extension, and isometric-resistive exercise with the exer-genie on speed of swimming as measured by the front crawl stroke and the prone flutter kick. Twenty male and 20 female swim team members were tested over a six wk. period and while both groups participated in regular daily swim workouts, the experimental group performed two additional exercises daily with the exer-genie. A cable tensiometer was used to collect data on arm and leg strength. A timed 50 yd. swim provided the data for both swimming and kicking speeds. No statistically significant differences were found.

Albrecht, R. C. (1958). Relationship between certain physique and flexibility measures and high school swimming success. Unpublished master's thesis, University of Wisconsin.

This study was to determine the relationship between measures of physique and flexibility and success in high school swimming. Eighty-nine varsity swimmers were given 14 physique and 3 flexibility measures. No relationship was found between these measures and swimming success.

Allen, J. G., & Noble, B. J. (1984). The relative influence of differentiated perceptions of exertion during swimming. Abstracts of Research Papers, AAHPERD, 100.

The purpose of this study was to determine the relative influence of differential perceptual ratings on the overall perception during swimming. Eighteen female college swimmers had heart rate and perceptions recorded following a 3 min. tethered ergometer swim at 25,50,75 and 100% of maximum working capacity. From a perceptual point of view, maintenance of swim velocities may be more a function of cues arising from local sources than central.

Alley, L. E., Asprey, G. M., & Tuttle, W. W. (1968). Effect of eating at various times on subsequent performances in the one-mile freestyle swim. Research Quarterly, 39, (2), 231-234.

Twenty-four subjects swam after time intervals of 1/2 hr., one hr., and two hrs., between swimming and eating a light meal. No adverse effect was noted on the swimming times after eating the cereal and milk meal (500 calories) for any of the time intervals.

Allik, T. A., Korobkov, A. V., Matvyeva, E. A. & Epstein, I. M. (1970). Energy basis of high work capacity in swimmers. Swimming Technique, 6, (4), 115-120.

Resting oxygen consumption of 4 champion swimmers was determined on days following training sessions. Work capacity increased in two stages. The first stage was characterized by an increase, the second by a decrease of oxygen

consumption during rest. The decrease of oxygen consumption was indicative of a highly effective adaptation of the organism to the sustained exercise schedule. It reflected a decrease in O2 consumption by the phosphorylization components of the cellular respiration chain. Economy of tissue respiration and oxygen utilization was most marked in adults. The onset of the second stage of training was facilitated by inclusion of orotic acid.

Andersen, K. L. (1960). Energy cost of swimming. Acta Chiroptica Scandinavica, (Suppl. 253), 169-174.

Oxygen consumption of 7 swimmers was found during swimming the breast-stroke. Great inter-individual differences were found in O2 cost of swimming, well trained swimmers having a superior efficiency. Dressed in uniforms and loaded with arms and military equipment increased the O2 intake by 1-1.5 1. A standard swim which exhausted the untrained swimmers was performed without strain by the skilled swimmers.

Andersen, P. (1976). The use of hand paddles, overload training, and after effects. Swimming Technique, 13, (2), 60-62.

Not an experimental study, but a review of studies on overload training concluding that for highly skilled swimmers paddles have little effect on pattern development and later performance. Errors in hand position should be easily detected with beginning swimmers.

Andrews, G. M., Becklake, M. R., Guleria, J. S., & Bates, D. V. (1972). Heart and lung functions in swimmers and nonathletes during growth. Journal of Applied Physiology, 32, (2), 245-251.

Lung and heart function were studied over a 3 yr. period in children during swim training. Resting lung volumes, expiratory flow rates, and diffusing capacity during exercise were measured annually and cardiac output and related functions during graded exercise were measured once. Results were compared with similar measurements in a group of children not in training. Swimmers had larger lung volumes, larger vital capacities, higher expiratory flow rates, and the absolute diffusing capacity was significantly higher. No difference in stroke volume was found.

Apor, P. (1978). Spiroergometric follow-up of Hungarian swimmers-1971-1977. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp.170-176). Baltimore: University Park Press.

Spiroergometric tests were carried out on the members of the Hungarian national teams in May 1971, and consecutive years through 1976. Results are tabled. Correlations among swimming performances and spiroergometric parameters revealed specific tendencies. Body weight was positively related to VO2 max. and to swimming performance. A relationship was found between the resting DLCO and VO2 max. and max. O2-pulse. Cranking and running VO2 max. were negatively correlated. Results measured in the same training period

showed significant changes from year to year.

Araujo, C. G. S. (1978). Somatotyping of top swimmers by the Heath-Carter method. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 188-198). Baltimore: University Park Press.

The purpose of this study was to assess the similarities in somatotypes among top swimmers of Brazil and other countries to determine the validity of somatotype determination for swimmers. Sixty-five swimmers, 46 males and 19 females from the Brazilian and Indiana University teams were somatotyped. Results are tabled and discussed. It was concluded that somatotype seems to be an important factor in swimming performance.

Araujo, C. G. S., Pavel, R. C., & Gomes, P. S. C. (1979). Comparison of somatotype and speed in competitive swimming at different phases of training. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III, (pp. 329-337). Baltimore: University Park Press.

This study was done to analyze the relationship between ratings of somatotype components and sprinting speed in the water of competitive swimmers at four different phases of training. Eleven male and 5 female swimmers were somatotyped and timed while swimming three 25M sprints using the crawl stroke. This evaluation was done at four different phases of training. Although somatotype can be an important factor in swimming performance, it is not related strongly enough to allow predictions of changes in speed in the water.

Armbruster, D. A. (1931). A method for rating efficiency in swimming on the basis of cardiac response. Unpublished master's thesis, State University of Iowa.

This study was to devise a method for rating efficiency in swimming the side stroke on 5 swimmers using the pulse-ratio test to rate efficiency. The trained side stroke swimmer required about 24 strokes to produce a 2.5 pulse-ratio.

Asprey, G. M., Alley, L. E., & Tuttle, W. W. (1968). Effect of eating at various times on free-style swimming performance. Swimming Technique, 5, 73-81.

Three time intervals of one-half, one and two hrs. between eating a prescribed meal and swimming were used for 24 subjects who swam ten trials for 200 yd. swim. As a control the same subjects swam 10 trials when they had not taken any food for at least 3 hr. prior to each trial. It was concluded that the eating of a cereal and milk meal (about 500 calories) at the intervals used has, for both men and women, no adverse effect on the swimming times for the 200 or 400 yd. freestyle swims. None of the subjects reported suffering any adverse effects in the form of nausea or stomach cramps during or after the swims.

Astrand, P. O., Engstrom, L., Eriksson, B. O., Karlberg, P., Nylander, I. Saltin, B., & Thoren, C. (1963). Girl swimmers: With special reference to respiratory and circulatory adaptation and gynacological and psychiatric aspects. Acta Paediatrica Scandinavica, (suppl. 147), 1-75.

This major work on 30 girl swimmers, aged 12-16 yrs., from the top swimmers in 4 different clubs, were investigated with special reference to respiratory and circulatory adaptation, and gynacological and psychiatric aspects. Most of the girls came from families belonging to the upper social groups. Most of their parents had formerly been active athletes and were extremely interested in the girls, sports prowess, which they stimulated and facilitated. The girls had an advanced growth expressed as an increased height in relation to age and a somewhat early menarch. They had good or superior intelligence and were extroverted and energetic. The gynacological examination disclosed no signs of menstrual disturbance. The physiological studies showed that the girl swimmers, taken as a group, had an advanced functional development. The functional dimensions measured, i. e., lung volumes and heart volume as well as the functional capacity determined during maximal oxygen uptake, were significantly increased in relation to body size. The functional development was related to the training volume.

Aycock, T. M., & Graaff, L. H. (1932). An analysis of the respiratory habits of trained swimmers. Research Quarterly, 3, (2), 199-217.

The respiration habits of 22 trained swimmers who were proficient at different strokes were analyzed by means of the electro-pneumotometric method, developed by the authors. The graphs obtained are explained for several different speeds of swimming various strokes. It was found that three methods of respiration exist regardless of the stroke: the explosive type, the prolonged type, and a combination of the two. The respiration technique described also proved to be capable of pointing out faulty respiration habits.

Bachman, J. C., & Horvath, S. M. (1968). Pulmonary function changes which accompany athletic conditioning programs. Research Quarterly, 39, (2), 235-239.

Pulmonary function measurements were made on swimmers and wrestlers undergoing four months of typical athletic conditioning programs and on a control group involved in no conditioning program. Significant changes were found only in swimmers where functional residual capacity, residual volume, the ratio of residual volume, total lung capacity, and respiratory rate decreased with training. However, vital capacity increased due to an increase in inspiratory capacity. Total lung capacity and expiratory reserve volume remained unchanged. No significant alterations occurred in the pulmonary functions measured in the other two groups of subjects.

Bagnall, K. M., & Kellett, D. W. (1977). A study of potential Olympic swimmers: 1. The starting point. British Journal of Sports Medicine, 11, (3), 127-132.

This study was done to assess the performance of each swimmer in order that a training regimen may be devised on a personal basis and to monitor the longitudinal effects of a very strenuous and vigorous training program continuous over the pubertal years of a select group of children. They were 9 male and 12 female swimmers ranging in age from 12 to 19 yrs. Individual profiles for these subjects reveal some outstanding physiological potential in terms of cardiovascular and cardiorespiratory adjustments to severe exercise.

Ball, J. R. (1953). Effects of immersion and mild exercise in water on the cardiovascular system. Unpublished master's thesis, University of Illinois.

Three males were tested to determine effects on the cardiovascular system of simple immersion and mild exercise in water of 76-80 degrees F. Measurements included blood pressure, pulse rate, grip strength, and oral temperatures. Systolic blood pressure was not effected. Pulse pressures increased in 2 of the subjects. Oral temperature decreased on immersion in water and decreased even further during exercise.

Ball, J. R. (1962). Effects of eating at various times upon subsequent performances in swimming. Research Quarterly, 33, (2), 163-167.

This study was conducted to determine what effect 6 different time intervals (1/2 hr., 1 hr., 1 1/2 hrs ... 3 hrs.) between eating and swimming have on the time required to swim 100 yd. free style. Ten measures of the time required for each of the 14 subjects to swim 100 yds. were obtained for each of the six time intervals after eating a small meal. The analysis of the data indicated that no one of the 6 intervals between eating and swimming had more effect on swimming times than any other.

Ballow, J. L. (1979). Relationship of vertical jump to swimming catagories for college females. Swimming Technique, 16,(3), 76-81.

Ninety-five female swimmers between 17 and 22 yrs. Were tested in the vertical jump to develop a jump range for the three distance classifications for college swimmers. Sprinters ranged from 17-22 inches, middle distance from 14-16 inches, and distance swimmers from 9-13 inches.

Barry, A. L. (1955). A comparison of the amounts of propulsive force exerted by two types of arm and leg action in swimming breast stroke. Unpublished master's thesis. State University of Iowa, Iowa City.

Bartels, R. L., Bowers, R. W., & Fox, E. L. (1963). Comparison of speed and energy expenditure for two swimming turns. Research Quarterly, 34, (3), 322-326.

Speed and energy expenditure of the closed and open turn while swimming freestyle were determined for 6 male swimmers. Resting metabolic rates were determined by a douglas bag open-circuit method. After performing a turn, the subject breathed into a Douglas bag for 15 mins. Each turn was timed with a stopwatch. A turn started three feet ten inches before touching and ended as the feet left the wall. Results showed no difference in energy expenditure for the two turns. However, the closed turn was significantly faster than the open turn.

Bastie, G. A. (1978). The effects of glycogen and fat loading diet on swimming performance during a championship meet. Swimming Technique, 15, (3), 87-88.

This study tested the effects of a diet on performance in a championship swim meet. The diet was given to the men's varsity swimming team with 4 swimmers using a fat-carbohydrate diet plan and 6 swimmers acting as controls with regular cafeteria food intake. The swimmers on the diet showed an improvement in performance times.

Beaudet, S. (1984). Comparison of swimming with running as training stimuli. Ergonomics, 27, 955-957.

A six week training program by 22 females, 12 in a swim program and 10 running were tested. Intensity level was adjusted so all subjects exercised at a level which produced a heart rate of 150 bpm for 12 mins. each session, 4 times a week. Using VO2 at a heart rate of 180 both groups showed improvement after 6 weeks of training. No significant difference was observed between the groups prior to or after training. A bicycle ergometer was used to test fitness.

Becker, W. M. (1954). Effect of cardiovascular condition and flexibility on the success of varsity and freshman swimmers. Unpublished master's thesis, University of Wisconsin.

This study was to determine what changes take place in swimmer's cardiovascular condition and flexibility as a result of a season of training and what happens after the cessation of training. In the 14 varsity swimmers tested the resting pulse rate decreased with training and recovery pulse returned to normal faster following strenuous activity. Harvard step test recovery rate decreased after a period of training and increased after a month's inactivity. A low resting pulse rate and a quick return to normal indicates good physical condition and is possibly related to good swimming performance. Swimmers tend to lose range of movement when no flexibility exercises are used during the season. Vital capacity increased as a

result of strenuous activity but decreased with inactivity.

Bell, G. H. (1978). The effects of two breathing patterns on selected physiological parameters during a simulated 200 yard freestyle in male swimmers. Unpublished doctoral dissertation, Virginia Polytechnic Institute and State University.

Belowich, D. L., & Sachs, M. L. (1978). Biorhythms and swimming performance: A comprehensive evaluation. Swimming Technique, 15, (3), 74-78.

The relationship of biorhythms to the swimming performance of 21 members of a mens varsity swimming team was examined. Two scales were used to measure position on the three biorhythms cycles. These were compared with two types of performance evaluations: a coaches subjective evaluation and an objective performance of swims. Results were generally not supportive of biorhythm theory.

Benson, N. Y. (1976). Physical working capacity of competitive swimmers following quantity and quality training and under contrasting ambient conditions 1. Swimming Technique, 13, (1), 13-15.

Fourteen swimmers from 8-20 yrs. were compared for PWC during quality as opposed to quantity training. Nine were also compared under two environmental conditions. No significant differences were found.

Benton, R. J. (1932). A study of the respiratory habits of trained women swimmers. Unpublished master's thesis, State University of Iowa.

The purpose of this study was to investigate the respiratory habits of 22 trained women swimming the crawl. Inspiration was shorter than expiration. Swimmers were classified according to three general types of respiration: explosive, prolonged, or a combination of these two.

Bestor, G. L. (1972). The effects of an isotonic weight training program on speed in three competitive strokes in college swimming. Unpublished doctoral dissertation, University of Arkansas.

This study was to compare the effectiveness of two types of training programs on competitive swimmers. One program involved interval swimming, kicking and pulling of competetive strokes, whereas the other added progressive repetition isotonic weight-training. Twenty male varsity swimmers were assigned to one of the two groups. The weight-training group took part in an isotonic weight-training program and an interval swimming program for 8 wks. The control group participated only in a program of interval swimming for 8 wks. An interval swimming program supplemented by the isotonic weight exercises was no more effective than an interval swimming program alone

in increasing speed in the 3 competitive strokes. Neither program changed body measures except for hip girth which was decreased by both. With untrained subjects a two-set progressive isotonic weight-training program significantly improves weight loads when used 3 days per wk. for a period of 8 wks.

Bloomfield, J., & Sigerseth, P. (1965). Anatomical and physiological differences between sprint and middle distance swimmers at the university level. Journal of Sports Medicine, 5, 76-81. Reprinted in Swimming Technique, 2, 63-67.

To determine anatomical and physiological differences between sprint and middle distance swimmers, 48 university swimmers were tested for specific gravity, strength, anthropometric measurements and cardiovascular fitness. It was concluded that the principal muscles of propulsion used in swimming by sprint swimmers were not significantly stronger than those of middle distance swimmers. Sprinters had significantly shorter thigh lengths than middle distance swimmers, but leg lengths were not significantly different. No significant differences were found pertaining to specific gravity and there were no differences in the bouyancy of sprinters and distance swimmers. Very little difference was noted in general body build between groups. Vital capacity of middle distance swimmers was greater than sprinters. They had slower heart rates and larger t wave amplitudes. Sprint swimmers had higher systolic blood pressures than middle distance swimmers.

Bonen, A., Belcastro, A. N., Simpson, A. A., & Ling, W. (1978). Comparison of LH and FSH concentrations in age group swimmers, moderately active girls, and adult women. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV, (pp. 70-78). Baltimore: University Park Press.

To determine whether strenuous swim training programs have a persistent effect on some of the circulating menstrual cycle hormones, the resting concentrations of LH and FSH were measured daily during one complete cycle in 4 young swimmers. Results were compared with those of an age matched control group and those of a group of fertile, adult women. The menstrual cycle of the swimmers was significantly shorter than that in the adults.

Borneman, E. H. (1951). Analysis of swimming ability and its relationship to constitutional body patterns. Unpublished doctoral dissertation, New York University.

Bradley, P. W., Troup, J., & Van Handel, P. J. (1985). Pulmonary function measurements in U. S. elite swimmers. Journal of Swimming Research, 1, (2), 23-26.

Twenty female and 18 male elite swimmers had pulmonary function measurements taken during training. Results revealed larger lung compartments and flow rates for elite swimmers than their normal predicted

values and for similar athletic groups.

Bugyi, B., & Kausz, I. (1970). Radiographic determination of the skeletal age of young swimmers. Journal of Sports Medicine and Physical Fitness, 10, 269-270.

This study was an investigation of the skeletal age of the best young swimmers of a sport school in Hungary. Eight girls and 28 boys ranging in age from 8 to 15 yrs. had radiographic determinations of skeletal age done on hand and wrist and on foot, ankle and knee. Acceleration of the development of young swimmers was found. This advance in skeletal age was seen as a positive effect on the youth tested.

Bullock, C. L. (1970). Relations of oxygen requirements with speed of swimming for men of championship ability. Unpublished master's thesis, Indiana University.

Burgess, W. C. (1953). Relation of selected variables with speed swimming. Unpublished master's thesis, University of North Carolina.

This study was to determine the relationship of body build, the Barach index, vital capacity, expiratory force, persistence time, flexibility, pull-ups, and vertical jump to time in the 100 yd. freestyle. Ten swim team members and 46 swimming class members were tested. Significantly better performances were found in the Barach index, vital capacity, average ankle flexibility, pull-ups and vertical jump among the swim team. The variables that could be best used for a test of potential swimmers were body build, the Barach index, vital capacity, ankle flexibility, pull-ups, and vertical jump.

Burke, E. R., Bartels, R., Hagerman, F., Hagerman, G., Kirkendall, D., & Nagel, S. (1978). The results of physiological testing on national class 14-17 year old male and female swimmers. Swimming Technique, 14, (4), 100-101.

The Wells sit and reach, the Margaria-Kalamen power, isokinetic strength, power and endurance tests and body compositions were given to 16 male and 28 female national class swimmers. The body composition data are in agreement with previous work. Power tests show the males more powerful than females.

Burke, E. R., Falsetti, H. L., Feld, R. D., & Patton, G. S. (1982). Creatine kinase levels during a season of training in competitive swimmers. Medicine and Science in Sports and Exercise, Abstracts, 14, (2), 134.

Creatine kinase was measured in 9 male competitive swimmers every 2 wks. during a season of training and competition. There was a 60% increase in creatine kinase level from early training

to peak training levels. During the taper phase of the season there was a significant decrease in these levels.

Caffrey, G. P. (1974). The physiological effects of chronic heavy physical training on male age group swimmers. Unpublished doctoral dissertation, The Ohio State University.

The purpose of this study was to determine the physiological, physical and anthropometric effects of age group training on 13 male age group swimmers ranging in age from 9-17 yrs. Thirteen males , untrained from the same area were matched with the swimmers according to age, ponderal index and body surface area. The control group did not participate in highly aerobic activities during the training period. The experimental group trained 6 days per wk. at about 12000M. per day. The variables measured on all subjects were overall body strength, selected skinfold measurements, body composition, maximal oxygen consumption, submaximal oxygen consumption, alactacid energy production, lactacid energy production, heart rate - resting, submaximal and maximal, and maximal exercise pulmonary ventilation. During the training, resting systolic intervals and submaximal cardiac output were measured on a selected sample of the experimental group. All metabolic measurements were made during exercise on a bicycle ergometer. Swimmers exceeded the controls in maximal oxygen consumption, aerobic capacity, alactacid capacity and maximal pulmonary ventilation. The swim group revealed significant increase in maximal exercise heart rate, body density and gross strength. A significant decrease in percent body fat was found in this group. The control group increased significantly in maximal oxygen consumption, aerobic capacity, gross strength, and strength quotient based on chronological age and weight. No significant changes were found after training in lactacid capacity, blood lactic acid concentration and respiratory exchange ratio.

Caldwell, J. E., & Pekkarinen, H. (1982). A comparison of aerobic thresholds and blood lactate responses during bicycle ergometry and free swimming. Proceedings of the V International Congress on Biomechanics and Medicine in Swimming.

Anaerobic thresholds and blood lactate responses were determined for 9 trained swimmers using the bicycle ergometer and free swimming. Swimming threshold was reached at 77.8% of maximum workload, while ergometer threshold occured at 51.5% of maximum. Blood lactate responses at the same workload were 58.5% and 31.4% respectively. it was concluded that bicycle ergometry for determination of submaximal values, anaerobic threshold, is inappropriate.

Calloway, E. C., & Hewitt, J. E. (1936). Alkali reserve of the blood in relation to swimming performance. Research Quarterly, 7, (1), 83-93.

Alkaline treatments, such as administration of organic salts of bases in food or in concentrated form, appeared to improve swimming performance. On the other hand, habitual acid diet, colds or other ills, where acidosis is a symptom, seemed to

reduce the efficiency in swimming performance. Titration of urine before and after swims indicated that severe physical exercise rapidly depletes the alkaline reserve of the blood.

Campbell, C. R. (1948). Study in the relationship of arm and shoulder strength to speed and endurance in free style swimming. Unpublished master's thesis, State University of Iowa.

To measure the relationship of arm pullover strength, as measured by a pullover test, to speed in the 50 yds. crawl and to swim endurance, measured by time for a 200 yd. swim and to determine the relationship between propulsive force generated by the arms and full stroke as recorded on a spring scale, to speed in swimming 50 yds. and 200 yds., 30 swimmers were tested. Arm and shoulder strength was highly related to speed in swimming 50 yds. freestyle. Arm strength was far more important to freestyle swimming than the legs. There was no marked relationship between arm strength and endurance.

Campbell, W. A., Jr. (1978). Relationship between bouyancy of the black male and learning the crawl stroke. In F. Landry & W. A. R. Orban (Eds.), Biomechanics of Sports and Kinanthropometry (pp. 149-155). Miami: Symposia Specialists Incorporated.

This study was designed to determine if there was a relationship between bouyancy of the black male and his ability to learn the crawl stroke and the selected skills in the crawl stroke. Thirteen black males were given ten lessons in the crawl stroke and specific gravities were determined. A positive relationship was found between bouyancy and learning selected skills in the crawl stroke.

Carlile, F. (1956). Effect of preliminary passive warming on swimming performance. Research Quarterly, 27, (2), 143-151.

The effect of preliminary heating by eight-minute hot showers was investigated in a group of male swimmers. An improvement was found when the passive warming preceded performance, compared to no warm-up. This improvement was statistically significant. Evidence as presented indicated that this improvement can not be explained psychologically as the result of suggestion.

Carlile, F., & Carlile, U. (1962). Physiological studies of Australian Olympic swimmers in hard training. Australian Journal of Physical Education, 12, 5-34.

This study was undertaken to obtain basic information on changes occuring during hard swim training on 16 male and 12 female members of the 1960 Australian Olympic swimming team. Brachial pulse wave measurements showed improvement in all aspects of wave measurement in all swimmers. Both resting and exercise blood pressures increased in lying. Systolic pressure and diastolic pressures gradually decreased as training continued.

Training increased pulse pressure due to the rise in systolic pressure and fall in diastolic pressure. There was a progressive falling off in diastolic pressure after the standard exercise. Lying electrocardiograms showed an increase in height of the r wave and a decrease in height of the t wave. Overall average weight of male swimmers was unchanged while the women gained an average of 3 lbs. Blood hemoglobin levels in these swimmers could not be differentiated from those of the general population. Cattell's sixteen personality factor questionnaire was given and the average scores of the group showed very little difference from the normal average.

Carter, J. E. L. (1966). Somatotypes of swimmers. Swimming Technique, 3, 76-79, 93.

This study was to describe the somatotypes of 24 outstanding college swimmers and to compare their types with other groups reported in the literature. The typical swimmer had somatotype largely endo-mesomorphic, with some ecto-mesomorphs and a few meso-ectomorphs.

Cerny, F. J. (1972). Rest and exercise pulmonary gas exchange in man during immersion in water. Unpublished doctoral dissertation, University of Wisconsin.

To observe changes in rest and exercise pulmonary gas exchange with immersion in water, 6 subjects were tested at rest and over 3 exercise levels. Work load in water was adjusted so that VO2 was equal under each condition. Measurements of O2 uptake, min. ventilation, its components, frequency, and tidal volume were taken. Arterialized blood lactate, hematocrit, hemoglobin, ph, and blood gases as well as heart rate were taken throughout the testing period. The only significant differences between the two environments were in pulmonary diffusing capacity and capillary volume measurements. Immersion caused a significant increase in rest capillary volume measurements. Which was reflected in an increased resting pulmonary diffusing capacity. This significant difference was maintained at the lightest work load, but was eliminated with increasing volume.

Charbonnier, J. P., Lacour, J. R., Riffat, J., & Flandrois, R. (1975). Experimental study of the performance of competitive swimmers. European Journal of Applied Physiology, 34, 157-167.

Cherne, A. R. (1957). Relationship of physique measures and success rating to swimming team performance. Unpublished master's thesis, University of Wisconsin.

Chivers, K. C. (1952). An inquiry into present day practices in conditioning competitive swimmers. Unpublished master's thesis, Springfield College.

The purpose of this study was to gather information regarding in water and out of water conditioning methods being used by collegiate swimming coaches in the United States and then to reach some conclusions from the survey of coaches' opinions which would serve as a basis for determining conditioning methods for the future. A summary of coaches practices and conclusions are made concerning swimming training programs in the early 1950's.

Clark, D. F. (1965). The effect of prescribed isometric exercise as it relates to thrust, speed, and endurance in swimming the front crawl. Unpublished master's thesis, Central Michigan University.

This study was to investigate the effect of prescribed isometric exercise on thrust, speed, and endurance for the average male college swimmer. Thirty-two male students were equated according to ability to apply thrust in the water and swimming ability. They were divided into groups and practiced training together for 8 wks. The experimental group practiced prescribed isometric exercise for 10 min., 5 days per wk. also. Data were collected for pre-test and post-test results on the ability to exert thrust in the water, ability in swim speed and ability for endurance swimming. The experimental group made significant gains in ability to apply thrust and the control group did not. Both groups made significant gains in ability to increase swimming speed. The experimental group's gain was significantly more than the control group's gain. Both groups made comparable significant gains in endurance swimming. There was no significant difference between the two groups.

Clarys, J. P. (1978). An experimental investigation of the application of fundamental hydrodynamics to the human body. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 386-394). Baltimore: University Park Press.

The purpose of this study was to investigate the application of a number of fundamental hydrodynamic principles to the human body. Nine competitive swimmers from the Netherlands and 44 physical education students acting as controls were tested in a high speed tank to measure drag forces. Results are tabled. It was concluded that fundamental hydrodynamics is related only to passive drag determination and not all the commonly used hydrodynamic principles can be applied on the human body.

Clarys, J. P., & Jiskoot, J. (1975). Total resistance of selected body positions in the front crawl. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp.110-117). Baltimore: University Park Press.

This study examined the total resistance (drag) associated with two selected front crawl body positions at five different velocities. Forty-three male swimmers were towed in these two positions and data recorded. Significantly less resistance occurred for the side position as compared to the prone position at the lower velocities. No differences were found at the higher velocities.

Collis, M. L. (1970). The effects of a sustained training program of breath-hold swimming on selected physiological parameters and swimming performance. Abstract Papers, AAHPER Convention.

Twenty-eight age group swimmers aged 11-14 were tested under the same swimming training program except that half of the group was given daily no-breath swimming as a part of their work out over an eight week period. Results showed that this experimental group had significant improvement in performance over the control. They also showed significant increases in vital capacity and increased ability to take up oxygen during a no-breath swim. It was concluded that no-breath work was a valuable addition to the training of competitive swimmers.

Cook, B., & Brynteson, P. (1973). Effect of a season of collegiate swimming competition and training on selected responses. Research Quarterly, 44, 63-69.

Eight varsity swimmers were tested 5 times with 5 wks. between tests. Starting at the beginning of the swim season, and ending with the end of the season. Swimmers were measured and tested for maximal VO2, maximal VE, VE/VO2, FVC, leg power, upper arm and shoulder endurance, percent body fat and weight. Anova found significant in season mean differences among the tests in percent body fat, FVC, endurance dips, and maximal VE. Regression statistics found only one significant trend. It occured in endurance dips that showed a significant positive linear regression. Significant differences shown among other variables did not occur in any predictable fashion.

Costill, D. L. (1965). The effects of water temperature on oxygen consumption, rectal temperature, and heart rate during strenuous exercise. Unpublished doctoral dissertation, Ohio State University.

The purpose of this study was to determine the effects of 3 swimming pool water temperatures on the metabolic responses of man during 3 min. of maximal work in water. The 3 temperatures were 64, 77, and 90 degrees F. Four varsity swimmers were tested. Exercise requirements were regulated by a swimming ergometer while each subject performed the flutter kick. Analysis of heart rates, oxygen consumption, and rectal temperatures suggested that a uniform energy requirement was needed to perform 3 min. of maximal exercise in water at these temperatures. There was greater hyperventilation in water at 64 degrees than in that of 77 degrees F.

Costill, D. L. (1966). Use of a swimming ergometer in physiological research. Research Quarterly, 37, 564-567.

Introduces a belt apparatus attached to swimmer with a spring gauge measurement at opposite end to show force exerted. Thirteen subjects indicated that exercise requirements imposed on them in water can be regulated while

swimming in a stationary position. The ergometer was found to be a reliable instrument for controlling the exercise requirement in the water.

Costill, D. L. (1978). Muscle biopsy research: Application of fiber composition to swimming. Proceedings from Annual Clinic of American Swimming Coaches Association.

This is not an experimental study, but an article to claify some technical aspects of the biopsy procedure, to show its practical use, to suggest some non-invasive ways of approximating muscle fiber composition and to illustrate some of the adaptations which occur in muscle as a result of aerobic and anaerobic training.

Costill, D. L. (1978). Adaptations in skeletal muscle during training for sprint and endurance swimming. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 233-248). Baltimore: University Park Press.

Review of adaptations in skeletal muscle during training. Not an experimental study.

Costill, D. L., Fink, W. J., Hargreaves, M., King, D. S., Thomas, R., & Fielding, R. (1985). Metabolic characteristics of skeletal muscle during detraining from competitive swimming. Medicine and Science in Sports and Exercise, 17, (3), 339-343. Reprinted in Swimming Technique, 22 (2), 15-18.

After 5 mo. of intense training, 8 male swimmers were studied during 4 wks. of inactivity. Biopsy specimens from the deltoid muscle revealed that its respiratory capacity decreased by 50% after one wk. of inactivity. Four wks. of detraining had no effect on enzyme activity however. Dispite metabolic changes during 4 wks. of inactivity, the swimmers' arm muscle strength remained unchanged or elevated during this same period. These observations demonstrate that while inactivity produced a dramatic decline in muscle respiratory capacity after one week of detraining, decrements in endurance and strength performance occured more slowly.

Costill, D. L., King, D. S., Thomas, R., & Hargreaves, M. (1985). Effects of reduced training on muscular power in swimmers. The Physician and Sportsmedicine, 13, (2), 94-101. Reprinted in Swimming Technique, 22, (1), 23-26.

Seventeen male college swimmers were studied before, during and after 14 days of reduced training (tapering). Maxiaml arm power was measured using a biokinetic swim bench and during a tethered swim test, and each swimmer also swam 200 yds. at an evenly paced velocity corresponding to 90% of his best performance of the season. Tapering had no influence on postexercise acid-base balance, but there was a significant increase in power output on both the biokinetic swim bench and the tethered swim test.

Costill, D. L., Sharp, R. L., & Troup, J. P. (1980). Muscle strength: Contribution to sprint swimming. Swimming World, 21, 29-34.

Forty-one swimmers were timed for a 25 yd. sprint from a pushoff to determine the relationship between maximum power on a swim bench and the sprint time. Five swimmers were studied before and after a strength training program to determine how much improvement in sprint swimming accompanies gains in muscular strength. Swimmers increased their power an average of 28%, while sprint performance improved 3.6%.

Costill, D. L., King, D. S., Holdren, A., & Hargreaves, M. (1983). Sprint speed vs. swimming power. Swimming Technique, 20, (1), 20-22.

To determine the relationship between a power swim test and sprint swimming performance, 30 swimmers were timed for a series of 25 yd. freestyle sprints from a pushoff. This time was used to calculate peak sprint velocity. Peak swimming force was calculated from trials on an adapted biokinetic swim bench. Small differences in sprinting speed were associated with measurable differences in swimming power and peak force. Swimming power correlated 0.82 with sprinting velocity.

Craig, A. B., Jr. (1973). Effect of age on maximal swimming velocity. Medicine and Science in Sports, Abstracts, 5, 63.

Results of the 1971 National AAU adult age groups swimming championships were examined. It was noted that mean velocities of the winners decreased linearly with age.

Craig, A. B., Jr. (1979). Fallacies of hypoxic training in swimming. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III, (pp. 235-239). Baltimore: University Park Press.

This study was designed to stimulate the effects of varying the breathing frequency during swimming on a single 26 yr. old male. Breathing less frequently probably does not accomplish anything that cannot be done by swimming faster.

Craig, A. B., Jr., & Boomer, W. F. (1980). Relationships between tethered and free swimming the front crawl stroke (abstract). Journal of Biomechanics, 13, 194.

Craig, A. B., Jr., Boomer, W. F., & Gibbons, J. F. (1979). Use of stroke rate, distance per stroke, and velocity relationships during training for competitive swimming. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III, (pp. 265-274). Baltimore: University Park Press.

A stroke meter was developed to measure stroke rate, distance per stroke and velocity while swimming. The relationships are reduced to a nomogram for calculating these parameters.

Craig, A. B., Jr., & Pendergast, D. R. (1979). Relationships of stroke rate, distance per stroke and velocity in competitive swimming. Medicine and Science in Sports, 11, (3), 278-283. Reprinted in Swimming Technique, (1980), 17, (1), 23-29.

Members of a collegiate swimming team were instructed to pushoff from the end of the pool and swim one length (22M.) at a constant velocity using minimum number of strokes and trying to achieve maximum distance per stroke. The time and distance to swim a predetermined number of strokes were measured during each swim of all 4 competitive strokes, and from these data the stroke rate, distance per stroke and velocity were calculated. The relationships of stroke rate and velocity in the 4 stroke patterns show an increasing velocity was achieved by a combination of an increase in stroke rate and a decrease in distance per stroke.

Cullen, F. P. (1954). Relationship between strength of selected muscle groups and the breast stroke kick. Unpublished master's thesis, University of Iowa.

The purpose of this study was to determine the relationship between the strength of the hip joint muscles and the strength of the breaststroke kick. the muscle groups tested were the hip adductors, abductors, extensors, flexors, inward rotators, and outward rotators. Data from the 46 females tested found no evidence of a relationship between force of the breaststroke kick and strength of the hip joint muscle groups.

Cunningham, D. A., & Eynon, R. B. (1973). The working capacity of young competitive swimmers, 10-16 years of age. Medicine and Science in Sports, 5, (4), 227-231. Reprinted in Swimming Technique, (1975), 12, (2), 39-46.

The physical work capacities of 43 competitive swimmers, 10-16 yrs. of age, were determined on a discontinuous steady-state bicycle ergometer test. Heart rates, oxygen uptakes and blood lactates were measured. The maximal oxygen uptakes ranged from 40.5 ml/kg min. for the older girls to 56.6 for the older boys. In comparison with a relatively elite group of 22 yr. old competitive swimmers the younger athletes had similar maximal oxygen uptake values. The development of speed and endurance in outstanding swimmers appears to be primarily dependent upon the maintenance of aerobic capacity started in early pre-pubertal growth years and subsequent development of strength, swimming

skill and capacity for anaerobic metabolism as the young swimmer matures.

Cureton, T. K. (1930). Relationship of respiration to speed efficiency in swimming. Research Quarterly, 1, (1), 54-70.

A preliminary report on the analysis of respiration and how it effects swimming. Investigation was done primarily with the use of a pneumograph. Aspects covered are simple immersion in the water, breathing drills, before immersion, effect of water pressure on respiration, respiration during swimming, and breathing techniques for maximum results in swimming performance.

Cureton, T. K. (1940). Review of a decade of swimming research at Springfield College. Research Quarterly, 11, 68-79.

This review groups experimental research completed at Springfield College from 1929-1939 into beginning, intermediate and advanced level studies and administrative, program, and scientific studies. Seventy-two references are cited.

Cureton, T. K. (1941). Flexibility as an aspect of physical fitness. Research Quarterly, 7, 381-390.

This study compares flexibility of average students to various swimming groups. Better speed and endurance in swimming performances parallel greater flexibility in the major joints.

Daggett, A., Davis, B., & Simpson, D. (1980). The physical working capacity of young girls involved in a moderate swimming regime. Swimming Technique, 16, (4), 106-108.

This study was designed to compare selected fitness parameters of 7 young girls involved in a swimming program of moderate intensity with a normally active group of girls of similar age. Changes were observed in functional capacity with the swimmers superior. When expressed as a function of body weight the swimmers were dominant, demonstrating an 11% improvement in conjunction with a 9% decrease in the control group. Differences were not statistically significant.

Dale, A. F., & Plyley, M. J. (1984). Sport specific vs. non-specific training and swimming performance. Medicine and Science in Sports and Exercise, Abstracts, 16, (2), 184.

Thirteen female intercollegiate swimmers were assessed every three weeks over a competitive season. Divided into two groups a tethered group underwent a combination of swimming and tethered swim training, with emphasis on stroke specific weight training. Another group undertook

swimming and weight training for development of swimming musculature. Force, work, power and muscular endurance were measured on the biokinetic swim bench. Data emphasize the importance of specific training to elicit performance gains.

Davis, J. F. (1955). Effect of weight training on speed in swimming. The Physical Educator, 12, (1), 28-29.

This study was done to observe the effect of weight training upon speed in swimming the crawl stroke. Seventeen male college subjects who possessed skills comparable to competitive swimmers were tested over a ten wk. period. The weight training period consisted of 3 workouts weekly. During the first and tenth weeks each subject was timed in the 25 and 50 yd. dashes. After the weight training period all subjects increased speed in swimming the crawl stroke. Weight training was found not detrimental to swimming, but highly beneficial.

Davis, J. F. (1959). Effects of training and conditioning for middle distance swimming upon various physical measures. Research Quarterly, 30, (4), 399-412.

Thirty male college students (non-varsity swimmers), that could swim 200 yd. crawl stroke, were used to analyze the effects of training and conditioning for the 200 yd. crawl stroke event upon certain physical conditions. Selected measures of cardiovascular condition, general physical fitness, gross strength, motor fitness, and strength of muscle groups used in swimming the crawl stroke were taken before and after the experimental period. In addition, the relationships between speed in swimming the 200 yd. crawl stroke event and the various selected tests were studied. Scores on the tests used to measure physical fitness, motor fitness and gross strength improved significantly after training and conditioning period. No significant difference was observed for the cardiovascular condition. Also, no correlation was obtained that was of value for prediction of swimming time.

Davis, M. G. (1966). Relative effects of two types of training on speed of swimming. Swimming Technique, 3, 90-92.

The purpose of this study was to determine the effects of two types of training on speed of swimming 60 yds. using the crawl stroke. In one method the practice was divided into kicking, pulling, and whole stroke drills. The other involved only whole-stroke swimming. Also tested were the effects of the two methods on speed in kicking 30 yds. and pulling 30 yds. Forty-six male subjects who had competitive swimming backgrounds or had completed advanced swimming were timed in a 60 yd. sprint and for 30 yds. kicking and pulling before and after the 4 wk. training period. One group trained under the interval-repetition method and had each day a warm up, kicking drills at 80% pace, pulling at 80% pace and whole stroke at maximum pace. The other group had warm up, whole stroke drills at 80% pace, and whole

stroke at maximum rate. The total distance swum each period was the same for both groups. There was a significant improvement in speed of swimming 60 yds. of the crawl stroke, kicking and pulling 30 yds. during the 4 wks. of training using either method, but no difference between the 2 programs.

Davis, R. G. (1965). The effect of increasing interval training pace or distance repetitions on swimming speed. Unpublished master thesis, Pennsylvania State University.

This study was to determine the effect of increasing the pace or the number of distance repetitions in interval training on swimming speed. In one method of training, 33 subjects kept the distance, the pace, and the rest interval during any one practice constant, while they increased the number of distance repetitions per practice. Another group of 31 had a training schedule in which the number of distance repetitions, the distance, and the rest interval during any one practice were held constant, while the pace was increased. A third group of 25 was a control group and did not participate in any swimming during the training period. All were men in the physical education program on the university level. The training lasted for 7 wks. and included 22 training days. A test of swimming speed over a 90 yd. distance was given before and after the training program. The speed of swimming the crawl stroke was improved by both experimental methods, but neither appeared better than the other.

DeRoanne, R., Pirnay, F., Dujardin, J., & Petit, J. M. (1971). Mechanical properties of the lungs during swimming. In L. Lewillie & J. P. Clarys (Eds.), Proceedings of the First International Symposium on Biomechanics in Swimming (pp. 207-215). Brussells: Universite Libre de Bruxelles.

The aim of this study was the measurement of the modifications of the pulmonary flow resistances and lung elasticity induced by submersion in water during swimming the breaststroke and the back stroke. Compliance and conductance values for 3 subjects were measured under 6 conditions. The average compliance obtained under normal conditions was 357 ml/cm. H2O. This value does not change greatly either while in ventral decubitus or while swimming breaststroke. It decreases sharply during submergence in the standing position. Weakest values were obtained during back stroke and in dorsal decubitus.

Devries, H. A. (1946). Study of the relationships between specific gravity and speed and endurance in swimming. Unpublished master's thesis, University of Texas.

The purpose of this study was to determine the specific gravity of men swimmers in relation to swimming speed and endurance, and skill and strength. Fifty men students of which 31 were varsity swimmers and 19 were good swimmers were tested. Procedures used in measuring specific gravity, speed, skill, endurance, and strength were described. If was considered doubtful that specific gravity was a factor influencing a swimmers speed on 100 ft. or 100 yd. distances. Strength had a negligable relationship with speed in the 100

ft. distance and only a slight relationship with speed in the 100 yd. swim. Skill appeared the most important factor in determining swimmers times for both 100 ft. and 100 yd. distances. There was a low correlation between endurance and speed in the 100 yd. swim.

Devries, H. A. (1959). Effects of various warm-up procedures on 100 yard times of competitive swimming. Research Quarterly, 30, (1), 11-20.

Thirteen subjects swam a total of 195 time trials. Each swimmer swam three 100 yd. time trials with no warm-up and three trials after each of the following warm-ups: hot shower, calisthenics, massage, and swimming. The group as a whole showed significant improvement after the swimming warm-up. The breaststrokers and butterfliers had their best and most significant improvement following calisthenics. The freestylers as a group showed significant decrease in speed following the calisthenic warm-up.

Dick, B. V. L. (1968). Comparative study of distance, interval and mixed methods of training for competitive swimming. Unpublished doctoral dissertation, Indiana University.

This study was to determine if there is a significant difference in swimming performance and cardio-respiratory endurance, of selected training procedures by 59 non-competitive swimmers. The interval and mixed programs were more effective than the distance program in developing swimming speed as measured by the 100 yd. swimming test. The interval training was more effective than either the distance or mixed programs in developing circulatory-respiratory endurance. The interval training was more effective than the distance or mixed programs in developing increased maximal oxygen intake. Twenty training sessions of 40 min. extended over a 10 wk. period were sufficient time to bring about physiological changes within the body.

Dicker, S. G., Lofthus, G. K., Thornton, N. W., & Brooks, G. A. (1980). Respiratory and heart rate response to tethered controlled frequency swimming. Medicine and Science in Sports and Exercise, 12, 20-23.

The purpose of this study was to investigate the respiratory and heart rate responses to tethered controlled frequency breathing (CFB) swimming. Nine elite college swimmers were given tethered swimming tests of 4 min. work bouts with 4 min. rest periods. Resisting forces during swimming were varied. Each subject was tested breathing every two (control), three, four, and five arm strokes. Subjects performed all four breathing frequencies at a constant arm stroke rate. As ventilatory volume decreased O2 extraction and estimated tidal volume significantly increased to maintain a constant O2 consumption for a given workload. CO2 production, respiratory exchange ratio, and heart rate did not change significantly in response to CFB. Estimated alveolar partial pressure of O2 decreased and partial pressure of CO2 increased significantly during CFB. However, estimated satuation of arterial blood with O2 was essentially undiminished during CFB. These responses do not indicate hypoxia

but rather hypercapnia during CFB.

di Prampero, P. E., Pendergast, D. R., Wilson, D. W., & Rennie, D. W. (1974). Energetics of swimming in man. Journal of Applied Physiology, 37, (1), 1-5.

Body drag and mechanical efficiency during swimming were measured on 10 men swimming the crawl at varying velocities. Body drag and mechanical efficiency was double that measured for passive towing.

di Prampero, P. E., & Pendergast, D. R. (1978). Blood lactic acid concentration in high velocity swimming. In B. Eriksson & B Furberg (Eds.), Swimming Medicine IV (pp.249-260). Baltimore: University Park Press.

The purpose of this study was to investigate the anaerobic contribution to energy expenditure in swimming from measurements of lactic acid in the blood, following the same approach applied by Margaria (1963) to running. Nine well trained swimmers were tested to determine overall energy expended during swimming from measurements of O2 consumption and of lactic acid accumulation in blood, without regard to the relative contributions of these two energy sources.

Dixon, R. W., Jr., & Faulkner, J. A. (1971). Cardiac outputs during maximum effort running and swimming. Journal of Applied Physiology, 30, 653.

This study measured O2 uptakes and cardiac outputs of 6 varsity swimmers for tethered swimming and treadmill running. In tethered swimming tests, the swimmer was attached to a pully system. The test consisted of 3 min. swims with a 3 to 5 min. rest interval. The starting work load was increased until the swimmer could no longer support the weight during the 3 min. swim. The treadmill running test consisted of 5 min. runs at 7 MPH, with a 10 min. rest between runs. The starting grade was 0 and was increased in each succeeding run until maximum voluntary physical work capacity was attained. The results indicate that there is no significant difference between the O2 uptakes and cardiac outputs for tethered swimming and those of treadmill running. A decrease in heart rate was observed for swimming as compared to running.

Doherty, J. A. (1977). The effects of an interval training regimen on selected anthropometric measurements of female high school swimmers. Unpublished master's thesis, Ithaca College.

Dulac, S., Leblanc, J., Cote, J., Jobin, M., Quirion, A., Brisson, G. R., & Decarufel, D. (1983). Metabolic and hormonal response to prolonged in swimming in cold water. Medicine and Science in Sports and Exercise, Abstracts, 15, (2), 95.

The acute effects of long distance swimming in cold water on selected hormonal and metabolic variables were evaluated on 6 professional long distance swimmers (5 male and 1 female) during a 38.5 km. swimming competition. The water temperature was 18 degrees C. and the mean performance time was 9 hr. and 19 min. An increase in plasma epinephrine, norepinephrine and cortisol and a decrease in glucose concentrations were observed after the race. It was suggested that the presence of cold water has an additive effect on the cortisol response to prolonged exercise.

Dummer, G. M., Clarke, D. H., Vaccaro, P., Vander Velden, L., Goldfarb, A. H., & Sockler, J. M. (1985). Age-related differences in muscular strength and muscular endurance among female master swimmers. Research Quarterly for Exercise and Sport, 56, (2), 97-110.

A group of 73 female masters swimmers aged 24 to 71, who trained an average of about an hour a day and 4 days a week, were tested to determine body composition, grip strength, peak shoulder and knee torque, and shoulder and knee movement endurance. While grip strength was highest among those in the 30-39 age range, in general, peak torque and strength values showed an age-related decline. The highest mean values for both shoulder and knee endurance were found among swimmers aged 50-59. Female masters swimmers exhibit greater muscular strength than do less active women of the same age as well as having relatively high knee and shoulder strength. Those over 60 showed a mean grip strength equivalent to that of less active females in their 20's and 30's. Swim training influences muscular endurance more than muscular strength among adult women.

Dupuis, R., Adrian, M., Yoneda, Y., & Jack, M. (1979). Forces acting on the hand during swimming and their relationships to muscular, spatial, and temporal factors. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 110-117). Baltimore: University Park Press.

The purpose of this investigation was to examine the muscular forces and the forces acting upon the hand with respect to the kinematics of swimming the back stroke and the breaststroke. Three female collegiate swimmers were tested. Data collection was done by electromyography, electrogoniometry, dynamography and cinematography. The use of strain gauge pressure transducers was found a valuable method for measuring forces on the hand during swimming.

Earey, P. F. (1963). Relationship of blood lactic acid and of various pace patterns to the efficiency of men in exhaustive swimming. Dissertation Abstracts International, 23, 4601-4602.

Subjects swam 200 yds. with 4 variations of pace patterns: constant, slow-fast, fast-slow, and slow-sprint. No significant difference existed between the patterns when using blood lactate accumulations and increases in heart rate as the criteria for determining effectiveness. Also, lactic acid was found to accumulate in the blood following cessation of exercise.

Edgerton, V. R. (1963). Performance in 400-yard swim after varying intervals of rest. Unpublished master's thesis, State University of Iowa.

The purpose of this study was to investigate the effect of 4 different intervals (24,48,72, and 96 hrs.) on the time required to swim 400 yds., on each of 3 consecutive days. Subjects were 7 varsity swimmers. rests periods used had no effect on the performance of a 400 yd. swim.

Edington, D. (1963). The relative effectiveness of two routines of resistive exercises for the arms in relation to speed in swimming the crawl stroke. Unpublished master's thesis, Florida State University.

Eighteen members of a university swim team were equated into two groups and a control group. The two experimental groups had specific weight training in addition to a swimming workout while the control group had swimming only. they were tested to determine to what extent two routines of weight training affected their speed in swimming the 100 yd. crawl. No significant differences among any of the groups was found.

Egolinski, E. A. (1940). Expenditure of energy in competitive swimming. Journal of Applied Physiology (London), 28, 700-706.

This reference may well be in error as our search for it has not been successful.

Engstrom, I., Eriksson, B. O., Karlberg, P., Saltin, B., & Thoren, C. (1971). Preliminary report on the development of lung volumes in young girls swimmers. Acta Paediatrica Scandinavica, (Suppl. 217), 73-76.

In order to look at the pattern of development of functional dimensions during hard physical training, a longitudinal study of a group of young girls at the beginning of their swim training was started in 1963. Lung volumes, heart volume, total hemoglobin, blood volume and maximal oxygen uptake were measured at regular intervals up to the age of 16. Twenty-nine girls were studied at the beginning of their training period and followed with exams once a year up to age 16. Nineteen of the girls had trained for 2 yrs. or less. Functional residual capacity, total lung volume and vital capacity were presented.

Eriksson, B. O., Engstrom, I., Karlberg, P., Saltin, B., & Thoren, C. (1971). A physiological analysis of former girl swimmers. Acta Paediatrica Scandinavica, (Suppl. 217), 68-72.

Thirty girl swimmers were re-examined 7 to 8 yrs. after their first exam and as a mean 5 yrs. after they had stopped regular swimming. Those girls who had had very large maximal oxygen uptakes, heart volumes, vital capacities and total hemoglobin values in relation

to age and body size had changed strikingly. Their mean maximal oxygen uptake was reduced from 52 to 37 ml/kg per min. The latter value is below the mean value found in untrained Swedish females of the same age. Their heart and lung volumes were not altered significantly but mean total hemoglobin had decreased by 13%.

Eriksson, B. O., Holmer, I., & Ludin, A. (1978). Physiological effects of training in elite swimmers. In B. O. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp,177-187). Baltimore: University Park Press.

The purpose of this study was to analyze the interrelationships among swim training, swim performance, and maximal aerobic power. Participants of a Swedish national swim team, 13 girls and 6 boys, all training at the same center were examined after 2 wks. of training and again after 8 mo. Nine of the swimmers improved there results, 4 had unchanged results, and 6 showed slighly impaired results.

Eriksson, B. O., Lundin, A., & Saltin, B. (1975). Cardiopulmonary function in former girl swimmers and the effects of physical training. Scandinavian Journal of Clinical Laboratory Investigations, 35, 135-145.

Sixteen former girl swimmers were studied before and after 12 wks. of physical training. They were selected from a group of 30 swimmers studied 10 yrs. previously. Maximum O2 uptake increased 14%, heart volume and vital capacity remained unchanged. Cardiac output and intrapulmonary gas exchange were studied in 6 girls. The stroke volume did not show the usual good correlation with heart volume. The increase in maximal O2 uptake after training was related to to the increase in stroke volume. No increase was found in values for pulmonary gas exchange nor in the maximal arteriovenous O2 difference. The results suggest that a long period of previous intense training does not significantly influence the maximal aerobic power later in life when again sedentary. The increase in maximal O2 uptake after training may not be large enough to prove advantageous when training is resumed.

Eriksson, B. O., Berg, K., & Taranger, J. (1978). Physiological analysis of young boys starting intensive training in swimming. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 147-160). Baltimore: University Park Press.

A longitudinal study of young boys starting regular swim training was initiated with 18 boys age 7-12, chosen because the subjects had not engaged in training for more than a few months. Physiological parameters are tabled and discussed.

Faulkner, J. A., (1966). Physiology of swimming, Research Quarterly, 37, (1), 41-54.

This review is directed toward the status of the physiology of

swimming and a delineation of needed research. It includes sections on body build, water resistance, muscle strength and endurance, circulation, respiration, temperature regulation, warm-up and swimming performance, energy expenditure, underwater swimming, and evaluation of performance, and a good review of research completed in physiology of swimming up to 1966.

Faulkner, J. A., & Dawson, R. M. (1966). Pulse rate after 50-meter swims. Research Quarterly, 37, 282-284.

To determine the relationship between swim velocity and pulse rate, 19 girls between 12 and 19 yrs. of age swam 50M. from a push-off at 25, 50, 75, and 100% of maximum speed. Water temperature was 19 C. and air temperature was 24 C. All subjects were expert swimmers. Elapsed time from push off to touch was recorded to the nearest tenth of a sec. Pulse rate was obtained by palpitation of the caroid artery from 15 to 30 sec. after the touch. The relationship between swim velocity and heart rate was reasonably linear in the front crawl, back crawl and breaststroke. The relationship in the butterfly was more curvilinear.

Fillipponi, M. (1951). The effects of warming-up upon the speed of swimming 100 yards. Unpublished master's thesis, Sprinfield College.

To determine effect of warm up on speed in swimming 100 yds., 12 varsity swim team members swam 100 yds. 5 times with a formal type of warm up and 5 times without warm up. No statistically significant differences were found between these times.

Fink, H. M. (1959). Specificity of conditioning in swimming and running. Unpublished master's thesis, University of California.

Foglia, G. F., Magel, J. R., Gatin, B., & Mcardle, W. D. (1973). Effects of training in swimming on maximum oxygen uptake. Medicine and Science in Sports, Abstracts, 5, 61.

Max. VO2 was determined on a treadmill running and tethered swimming test in 15 experimental and 15 control college age male recreational swimmers prior to and following a 12 wk. swim training program. Following the program VO2 max. increased significantly during swimming, but not during treadmill running. Max. heart rate decreased and ventilatory equivilant increased significantly in the experimental group during both running and swimming. Results support the high degree of specificity of training in swimming.

Fossum, K. S. (1942). Study of inter-relationships among various measurements made on a group of college women selected with special reference to swimming ability. Unpublished master's thesis, University of Oregon.

This study was to determine the inter-relationships among a large number of reliable tests and measurements purported to be related to the ability to swim, to investigate the correlation between such factors as anthropometric measurements, body build, specific gravity, propelling force, power and endurance to speed in swimming short distances, and to compare types of swimming strokes on the basis of propelling force and to investigate a reliable and simple means of measuring bouyancy and to review the literature on tests related to swimming ability. Sixty female college students were tested on height, weight, sitting height, chest circumference, shoulder width, and hip width. Bouyancy was determined by hydrostatic weighing. Propelling force of the crawl stroke, back crawl, breast and side stokes were recorded from a dynamometer. A time trial for 60 ft. and 120 ft. was used to indicate the ability to sprint short distances. The devices and methods used for purposes of measuring propelling force and specific gravity were found to be accurate and highly reliable. The differences among the mean propelling forces developed on the 4 swimming strokes compared were found to be statistically significant. The order of the strokes on which the greater propelling force was developed was found to be breaststroke, side stroke, front crawl, and back crawl.

Fox, E. L. (1961). Analysis of speed and energy expenditure of two swimming turns. Unpublished master's thesis, Ohio State University.

Gale, D. G., Butts, N. K., Kirkendall, D., & Hosler, C. F. (1982). Effects of training on the blood lipids and lipoproteins of intercollegiate swimmers. Medicine and Science in Sports and Exercise, Abstracts, 14, (2), 103.

This study was designed to determine if training would have an effect upon the concentrations of blood lipids and lipoproteins of male and female intercollegiate swimmers; and to determine if alterations in blood composition occured in the sexes differently while involved in similar training programs. Eighteen male and 20 female swimmers participated in an identical 8 wk. training program. It was concluded that 8 wks. of swim training was sufficient to cause significant changes in blood lipid and lipoprotein concentrations in male and female swimmers, and that these changes occured similarly in both sexes.

Gandelsman, A. B. (1967). The conditions of reaching high work capactiy during distance work. Theory and Practice of Physical Culture, Moscow.

Gardiner, J. B. (1972). Difference in flexibility between selected springboard divers, gymnasts, and swimmers. Unpublished master's thesis, Springfield College.

To determine differences in trunk, hip, shoulder and ankle flexibility between college age males involved in diving, gymnastics, and swimming,

subjects were tested with the Leighton flexometer to measure flexiblity around the joints. Subjects were 15 swimmers, 15 gymnasts and 12 divers. Swimmers were lower in flexibility on hip flexion and extension and divers were more flexible in shoulder movements then swimmers or gymnasts. No differences were found in range of motion of the ankle.

Gavreesky, W. S. (1963). Assessing the state of preparedness for swimmers. Journal of Sports Medicine, 3, 6-10.

Taking pulse rates immediately following and 1 min. following swimming performance on 165 swimmers, it was established that a better performance resulted in a lower coefficient. This coefficient was determined by dividing the sum of 10 sec. heart rate counts taken as indicated above into performance times in seconds. The coefficient was lowest for the best swimmer and increased with decline in performance. Work was done during 1960 International championships and 12th student games, so a maximum effort was assumed. The test was of value when applied to the same swimmer at different periods of time and different conditions. As training proceeds the coefficient for individual swimmers should drop. Thus offering a means of checking the state of fitness of the swimmer.

Geistweit, W. (1952). Relationship between the brachial pulse wave and metabolic measures and swimming time. Unpublished master's thesis, University of Illinois.

This study was to determine the relationships between the brachial pulse wave, metabolic measures and swim times. Forty-three subjects were tested for sitting basal gas, heartogram measures, 100 yd. drop-off swim, one min. exercise swim, first and second recovery gases and 440 yd. swim times. The faster swimmers had correspondingly larger brachial pulse wave cycle times. Faster 100 yd. swimmers had larger gross oxygen debts and oxygen requirements. Faster 440 yd. swimmers had larger gross oxygen intake, gross oxygen debt, and oxygen requirements. Swimmers with larger gross oxygen intake masures had correspondingly larger brachial pulse areas and diastolic amplitudes. Those with larger gross oxygen debt measures had correspondingly larger brachial pulse wave area, systolic amplitudes, diastolic amplitudes, diastolic surge amplitudes, and rest to work ratio. Swimmers capable of developing large oxygen requirement measures have correspondingly larger brachial pulse wave areas, systolic amplitudes, diastolic amplitudes, dicrotic notch amplitudes, and rest to work ratios.

Gergley, T. J., McArdle, W. D., Dejesus, P., Toner, M. M., Jacobowitz, S., & Spina, R. J. (1984). Specificity of arm training on aerobic power during swimming and running. Medicine and Science in Sports and Exercise, 16, (4), 349.

The specificity of aerobic training for upper body exercise requiring differing amounts of muscle mass was evaluated in 25 untrained college-aged male recreational swimmers randomly assigned to either a non-training control group, a 10-wk. swim training group, or

a group training with a standard swim bench pully system. Training groups improved to a similar extent, but the swim training groups VO2 was greater than that noted for the swim bench group. A comparison between the swim bench group and the swimming group on the treadmill support the specificity of aerobic improvement with training. Swim bench training was found effective for training the aerobic system during swimming.

Gibbins, J. A., Cunningham, D. A., Shaw, D. B., & Eynon, R. B. (1972). The effect of swimming training on selected aspects of the pulmonary function of young girls - A preliminary report. In A. W. Taylor & M. L. Howell (Eds.), Training Scientific Basis and Application. (pp. 139-143). Springfield, IL: C. C. Thomas.

The purpose of this study was to look at the effect of 6 mo. of swim training on the pulmonary diffusing capacity for carbon monoxide (DLCO) of 6 girl swimmers aged 9-10 yrs. compared with age-matched controls who were non-swimmers. Additional lung volumes were also measured. No significant changes were found.

Giese, W. K. (1965). Program of swimming interval training upon selected physiological parameters of the pre-pubescent male and female. Unpublished doctoral dissertation, Florida State University.

This study was to determine the effect of a program of interval training in swimming upon certain selected physiological parameters associated with cardiovascular system of pre-pubescents. Twelve swimmers, 4 female and 8 male, participated in the program. Significant changes were observed in systolic blood pressure at rest, systolic blood pressure immediately after exercise, pulse pressure immediately after exercise, and heart rate immediately after exercise.

Gilders, R. M., & Hagerman, F. C. (1982). A metabolic comparison of tethered swimming and swimming ergometer work. Medicine and Science in Sports and Exercise, Abstracts, 14, (2), 143.

Nine male college varsity swimmers were studied during tethered swimming with arms and legs, arms only, and during an inclined plane ergometer exercise, arms only. The energetics of swimming ergometer work and tethered swimming are not comparable. Results suggest use of ergometer as a possible training stimulus for anaerobic power.

Goedeke, J. F. (1955). Effect of physical and cardiovascular measures on success of varsity and freshman swimmers. Unpublished master's thesis, University of Wisconsin.

This study tested 19 varsity and freshman swimmers on a group of physical and cardiovascular tests administered during a pre-season period and again during a post-season period. The tests included physical measures of height,

weight, chest normal, chest expanded, chest deflated, gluteal girth, calf girth, torso length, bust height, arm span, shoulder width, thorasic width, hip width, back extension upward, front flexion forward, shoulder extension, ankle flexibility, bouyancy, vital capacity, and hand and feet surface areas. The cardiovascular measures were the Tuttle pulse ratio test and the 40 yd. pulse rate recovery test. Most anthropometric measures increased. Flexibility measures showed a decrease in all areas except back extension upward. Vital capacity increased. Bouyancy was reduced. Mean rested pulse rate decreased. The Tuttle pulse rate test seemed to differentiate between sprint and distance swimmers. No improvement was found in the 40 yd. swim pulse rate recovery test results. High intercorrelations were found between most anthropometric measures. Intercorrelations between most flexibility measures showed little relationship. An inverse relationship was found between front flexion forward compared with a success rating. Several physical measures showed an inverse relationship with a success rating. Outstanding swimmers seem to have large feet, large hands, long arms and greater height. Better recovery after cardiovascular tests seemed to be indicative of success.

Greene, M. M. (1930). Energy cost of track and swimming. Unpublished master's thesis, Springfield College.

The purpose of this study was to determine O2 requirements of exercise, O2 debt, and O2 intake incurred while running and swimming. Two subjects were tested running and two others tested swimming. The deduced times in swimming were close to the observed times. It was concluded that the most efficient method of running or swimming was to assume a constant speed and hold it throughout the exercise. For short vigorous exercises the speed was dependent mostly upon O2 debt. For greater distances, the O2 debt was insufficient and speed became more and more limited by the adequacy of the oxygen supply from the respiratory organs. For very great distance the O2 debt became insignificant and the speed approached a constant value determined almost entirely by pulmonary exchange.

Gregg, S. G., & Wilmore, J. H. (1982). Alterations in the post exercise lactate response following swim training. Medicine and Science in Sports and Exercise, Abstracts, 1, (2), 160.

Ten collegiate varsity swimmers were studied in an attempt to determine changes in plasma lactate values for standardized swimming velocities following swimming training. It was concluded that a training program of greater than 6 wks. was necessary for any significant alterations to occur in the lactate/swim velocity curve in collegiate swimmers.

Gregor, J. G. (1974). The effect of a progressive-weight-training program on the performance of swimming the 100-yard crawl stroke of male and female competitive swimmers between the ages of ten and sixteen. Unpublished doctoral dissertation, University of Oregon.

To investigate the influence of a progressive weight training program in performance of swimming the 100 yd. crawl stroke 40 competitive swimmers

between the ages of 7-17 were used as subjects. The experimental group of 20 was exposed to 9 wks. of training in a competitive swimming and progressive weight training program. the weight-training exercises consisted of warm up, one-half squats with barbell, latissimus exercise with wall pulleys, bent-over rowing, pullover with barbell, abduction of the arms and forearms with dumbells heel raises with a barbell, arm abduction with dumbells, and sit ups with a dumbell. The control group was exposed to an identical competitive swimming program, but did not participate in the progressive weight training exercises. Time for swimming the 100 yd. crawl stroke was the criterion for both groups. Participation in a weight training program did improve strength significantly in 7 strength exercises. Strength was improved in the other 9 strength measures, but not significantly. No significant increases in blood pressure scores, anthropometric measurements,or in vital capacity were found. A significant increase in performance in the 100 yd. crawl was found.

Hacker, H. (1957). Relationship of shoulder strength and weight to swimming speed. Unpublished master's thesis, Pennsylvania State University.

This study was to determine to what extent shoulder strength and body weight were concomitant with the speed of swimming crawl stroke. Five hundred and eighty-one male subjects were tested for swim speed for 75 ft., pull-ups, and distance a rope could be climbed in 8 sec. There was a negative correlation that was significant between pull-ups and swimming speed. A negative correlation that was significant between rope climbing ability and swimming speed indicated that swimming speed was significantly related to shoulder strength.

Hagerman, F. C. (1962). Comparison of oxygen debts in swimming the 400 yard freestyle while using the open and closed turns. Unpublished master's thesis, Ohio State University.

Net oxygen debts while swimming the 400 yd. freestyle using open and closed turns were determined on 5 male subjects. Each subject swam the 400 yds. within 5 sec. of the predetermined time performing either open or closed turns. No significant difference was found in oxygen debts accumulated by the subjects during the swims.

Haldi, J., & Wynn, W. (1946). Observations on efficiency of swimmers as related to some changes in pre-exercise nutriment. Journal of Nutrition, 31, 525-532.

Experiments on 12 swimmers indicated that the time required to swim each of three laps in a 100 yd. sprint was the same after a heavy meal as after a light meal eaten two and one half to 3 hrs. before swimming. An additional ingestion of 50-100 gr. of sucrose after the light meal, and one hr. before swimming had no effect on swim time. The drop-off in the 2nd and 3rd laps, which was taken as an index of fatigue, was the same regardless of amount of food intake before swimming. Blood sugar concentration immediately after swimming was about the same in all experiments regardless of the food intake.

Haldi, J., & Wynn, W. (1946). Action of drugs on efficiency of swimmers. Research Quarterly, 17, (2), 96-101.

Twelve college men were used to test the effect of metrazel, benzedrine, and caffeine alkaloid on swimming performance. It was found that administration of 100 milligrams of metrazel, 5 milligrams of benzedrine, or 250 milligrams of caffeine alkaloid, approximately one hr. before swimming had no effect on speed or rate of deceleration of speed in swimming a 100 yd. sprint.

Hamilton, R. (1984). Predicting meet times. Swimming Technique, 20, (4), 43-46.

This study was done to find a scientific yet practical method of predicting swimming performance. Eighty-three males and 16 females were timed for five 100 yd. swims on a 3 minute interval and a subsequent 200 yd. competitive swim within 1 wk. An equation was produced to predict time in upcoming competition from the results of the five 100 yd. swims.

Harvey, N. J. (1943). Study of the changes in muscular strength, size and endurance which occured in a swimming situation. Unpublished master's thesis, University of Oregon.

Hawkins, C. C. (1935). Effect of training in swimming upon the morphological composition of the blood. Research Quarterly, 6, (2), 59.

The purpose of this study was to investigate the changes occuring in the differential count of the white blood corpuscles during training in swimming. Eight men from the varsity swimming squad were tested before, during, and after the swim season, the blood being taken as often as every other day. Samples of the blood were taken before and after week-ends and vacations. Blood was taken either from the finger tip or ear lobe. The absolute as well as the differential counts were found. At the beginning of training there is an immediate rise in the younger forms of the neutrophiles, which reaches its maximum at peak of training and returns to normal soon after discontinuation of training. Swim training not only causes a redistribution of the white corpuscles, but also increases the activity of the blood forming tissues.

Healey, J. H. (1970). A comparative study to determine the relationship between plantar flexion at the ankle joint and success in selected skills in swimming. Unpublished doctoral dissertation, University of Utah.

This study was to determine if increased plantar flexion at the ankle joint produced any appreciable difference in propulsion during the execution of selected swimming skills. Both experimental and control groups in the 3 selected swimming skills and ankle plantar flexion measurements

improved significantly. Differences between control and experimental groups were significant in favor of the experimental group with respect to ankle plantar flexion, front crawl kick and dolphin kick.

Hebbelinck, M., Carter, L., & De Garav, A. (1975). Body build and somatotype of Olympic swimmers, divers, and water polo players. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp. 285-305). Baltimore: University Park Press.

Anthropometric measures of 66 male swimmers, 29 female swimmers, 16 male divers, 7 female divers, and 71 male water polo players; all athletes of the Mexico Olympic games were somatotyped according to the Heath-Carter anthropometric somatotype method. They show characteristic tendencies related to their sport. Variation within some events and sports is considerable, but in general they can be differentiated from athletes in some other sports.

Helmuth, H. S. (1980). Anthropometric survey of young swimmers. Anthropological Anz., 38, 17.

This reference may well be in error as our search for it has not been successful.

Hendrickson, C. B. (1949). Effect of development of foot flexibility on learning the flutter kick. Unpublished master's thesis, University of Wisconsin.

The purpose of this study was to determine the effect of developing foot flexibility on the learning of the flutter kick and the relationship of increased foot flexibility to increased swimming speed. Flexibility of the ankle joint was measured by a flexometer on 41 college females. They were grouped according to speed of flutter kicking 60 ft. Teaching was the same for both groups with the exception of the experimental group receiving foot flexibility exercises for the last 6 min. of each class period for 9 wks. Flexibility of the foot was increased by flexibility exercises. A greater increase in speed was shown by those receiving flexibility exercises.

Hesalroad, L. A. (1939). Comparison of the response of the hearts of college women to basketball and to swimming. Unpublished master's thesis, State University of Iowa.

This was a investigation into the heart response of 24 females skilled in both swimming and basketball. From the standpoint of recovery time basketball was more strenuous than swimming. There was a higher rate of increase in heart responses immediately following cessation of activity in swimming than in basketball. The greatest decrease in heart rate occured within the second half min. in basketball. Swimming showed a greater degree of recovery per min. up to 5 min. after recovery.

Hetherington, R. (1974). Influence of preliminary warmup on 100 yd. freestyle. Swimming Technique, 10, 125-126.

Nineteen college varsity swimmers were tested under 3 conditions. They were: Before work-out, a 100 yd. time trial taken before getting wet or any type of warm-up. Secondly, after 400 yd. time trial taken after a 400 yd. swim of stroke or strokes of swimmers choice. And then after 1800 yd. time trials taken after 1800 yd. workout. No significant difference exist between these test averages.

Heusner, W. W., Jr. (1955). Progressive changes in the physical fitness of an adult male during a season of training in competitive swimming. Unpublished doctoral dissertation, University of Illinois.

One subject was tested to determine changes in physical fitness during a competitive swim season. He was measured monthly, on 256 test items. He trained intensively 6 days a wk. for 8 wks. of land work and 15 wks. of pool work. Significant increases were found in chest girth and breadth, large increases were found in O2 intake. O2 debt during all-out exercise increased. Ability to use O2 increased. An increase in RBC after exercise was found. Quiet pulse rates decreased and gains were made in expiratory force and breath holding. Heart volumes decreased and heart functions were improved. Stroke volume before and after exercise increased. Power increased and flexibility decreased during land drills, but improved when swimming started. A gain in 3.9 sec. was made in 100 yd. drop-off during the swimming part of the program.

Hockey, R. (1965). Flexibility changes following three weeks of participation in a swimming program. Unpublished master's thesis, University of Oregon.

Hofer, S. W. (1969). The relationship between hip and shoulder strength and front crawl efficiency. Unpublished master's thesis, University of Iowa.

A significant correlation was found between hip extension strength and swimming efficiency. Female subjects derived more power from the arm stroke than from the leg stroke.

Holmer, I. (1971). Oxygen uptake during swimming at different speeds in the "aquatic swim-mill". In L. Lewillie & J. P. Clarys (Eds.), Proceedings of the First International Symposium on Biomechanics in Swimming (pp.199-205). Brussells: Universite Libre de Bruxelles.

The purpose of this experiment was to test the experimental set up and to measure the energy cost of swimming at different speeds. Three male and 3 females with differing backgrounds in swimming swam in the swim mill and oxygen uptakes were determined. The mean values for swimming were 85% of that recorded in running and 95% of that in cycling.

Holmer, I. (1972). Oxygen uptake during swimming in man. Journal of Applied Physiology, 33, 502-509.

Oxygen uptake, heart rate, and blood lactate concentrations were measured on 3 female and 6 male adult subjects with varying proficiency in swimming. Subjects swam in 3 styles at different speeds and while exercising on a bicycle ergometer and on a treadmill. The same determinations were made on 12 girl swimmers of 13-18 yrs. of age, but only during maximal running and maximal swimming. At a given swimming speed the trained swimmers were able to swim with a lower O2 uptake than untrained swimmers. At a given O2 uptake trained swimmers swam faster than the untrained. The front crawl was the most economical style of swimming, backcrawl was less and breaststroke least. Maximal O2 uptake, maximal pulmonary ventilation, and maximal heart rate were significantly lower in swimming than in running or cycling.

Holmer, I. (1974). Physiology of swimming man. Acta Physiologica Scandinavica, (Suppl. 407).

Holmer, I. (1974). Energy cost of arm stroke, leg kick and the whole stroke in competitive swimming styles. European Journal of Applied Physiology, 33, 105-118.

Maximum O2 uptake at a given velocity in freestyle and backstroke was lower on average as compared with breaststroke and fly in elite male swimmers. Except for breaststroke, swimming with arm strokes only demanded a lower VO2 at a given submaximal velocity than the whole stroke. In freestyle swimming and backstroke the submaximal VO2 of leg kick at a given velocity was higher than the whole stroke. The highest velocity during maximal swimming was always attained with the whole stroke, and the lowest with the leg kick, except for breaststroke, where the leg kick was most powerful. Highest values for VO2, heart rate and blood lactate during maximal exercise were almost always attained when swimming the whole stroke, the lowest when swimming with arms strokes only. At higher velocities body drag was lower when arms or legs were supported as compared with body drag without support.

Holmer, I. (1974). Propulsive efficiency of breaststroke and freestyle swimming. European Journal of Applied Physiology, 33, 95-103.

Swimming trials and determination of drag during passive towing took place in a swimming flume in which water flow rate could be varied. The average drag at a given rate of movement by 3 top swimmers was about twice as great in breaststroke and freestyle swimming as in passive towing with the body extended and horizontal in the water. The greatest degree of propulsive efficiency (7.7%) was calculated for the arm strokes alone in the freestyle. The freestyle and breaststroke produced values for efficiency amounting to 5.6 to 6.6% and 3.6 to 5.7% respectively.

Propulsive efficiency was calculated for the leg strokes only in the breaststroke and freestyle at 2.4 to 3.8% and 1.3 to 2.4% respectively.

Holmer, I. (1975). Efficiency of breaststroke and freestyle swimming. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp. 130-136). Baltimore: University Park Press.

To determine propulsive efficiency on the breaststroke and freestyle swimming, 3 highly skilled male swimmers were measured while swimming in a swimming flume. Data support the opinion that the major contribution to propulsion in freestyle is derived from the arms.

Holmer, I., & Astrand, P. O. (1972). Swimming training and maximal oxygen uptake. Journal of Applied Physiology, 33, 510-513.

Two female identical twins had oxygen uptake, heart rate, and blood lactic acid concentrations measured during exercise. Both were physical active, but one also participated in hard swimming training. The study involved swimming a swimming flume, running on a treadmill, and cycling on a bicycle ergometer with both submaximal and maximal work loads. The two girls performed separate arm and leg work in swimming, arm work, and combined arm and leg work on the bicycle. The highest maximal oxygen uptake was measured during running uphill and was almost identical in the two girls. In other exercises the trained swimmer reached higher oxygen uptake than her sister. The most pronounced difference was during arm swimming where the trained swimmer had a 49% higher oxygen uptake than her sister and could perform a much higher swimming speed.

Holmer, I., & Bergh, U. (1974). Metabolic and thermal response to swimming in water at varying temperatures. Journal of Applied Physiology, 37, (5) 702-705.

Five male sujects performed 20 min. submaxiaml and 5 to 8 min. maximal swimming. Esophageal and muscle temperature, O2 uptake, heart rate, and blood lactate were determined at different water temperatures. Lean subjects suffered a decrease in esophageal temperature during submaximal swimming in 18 degree C. water. Heart rate during maximal swimming was linearly related to esophageal temperature. VO2 max. was elevated by swimming in the colder water.

Holmer, I., & Gullstrand, L. (1980). Physiological response to swimming with a controlled frequency of breathing. Scandinavian Journal of Sports Science, 2, (1), 1-6.

Metabolic and cardiorespiratory responses of 8 swimmers were compared during a hypoxic swim training session with those during a training session with normal breathing. Oxygen uptake, pulmonary ventilation, and expired oxygen concentration were significantly lower during the controlled repeats compared with normal repeats. Heart rates and blood lactate values were not

significantly different under the two breathing conditions. Results lend no support to the view that hypoxic training has an advantage over normal swim training in increasing aerobic or anaerobic power. Controlled breathing may have some biomechanical effects however, improving stroke mechanics and reducing drag.

Holmer, I., Lundin, A., & Eriksson, B. O. (1974). Maximal oxygen uptake during swimming and running by elite swimmers. Journal of Applied Physiology, 36, (6), 711-714.

Eleven female and 12 male elite swimmers performed maximum running on a treadmill and maximum swimming in a flume. VO2, heart rate, and blood lactate concentration were determined in conjunction with exercise. There was a significantly lower VO2, heart rate, ventilatory equivilant and ventilatory coefficient in maximum swimming than in maximum running. The mean maximum heart rate was 15 beats per min. less in swimming than in running. Almost identical VO2 max. values were noted for 7 subjects swimming in the flume and at a maximum rate in a 50M. pool.

Holmer, I., Stein, E. M., Saltin, B., Ekblom, B., & Astrand, P. O. (1974). Hemodynamics and respiratory responses compared in swimming and running. Journal of Applied Physiology, 37, 49-54.

In 5 healthy males performing submaximal and maximal work in swimming and running, VO2, heart rate, and cardiac output were measured. At a given VO2 submax. during swimming and running the cardiac output, stroke volume, and heart rate were similar. On an average Vo2 max. was 15% lower, maximal cardiac output 10% lower, and maxiaml stroke volume about the same in swimming as compared to running. Mean arterial blood pressure was higher during swimming. Maxiaml values for blood lactate were similar in the two modes of exercise.

Homola, D., & others. (1966). Changing picture of ventricular pre-excitation in a first-class swimmer. Journal of Sports Medicine, 6, 33-37.

Under the influence of sympatol a transitory lowering of the activity of the sinus node but also a lowering of the impulse formation in the a-v node took place. The heart of trained individuals can reach a desired rise of the minute volume in extreme activity even when a ventricular contraction comes so soon that systole of the atria cannot fill the contents of the chamber with blood.

Houston, M. E. (1980). Diet, training and sleep: A survey study of elite Canadian swimmers. Canadian Journal of Applied Sport Science, 5, (3), 161-163.

A three day survey of food intake, training and sleep patterns was completed by 8 male and 12 female elite Canadian swimmers. Both groups swam similar distance and had similar flexibility and

strength programs. Males average 5 and females 4 meals per day. Males ate more food, taking in more than twice the calories as the females. Twelve of the 20 swimmers took additional food supplements. Both groups slept for similar periods of time each day.

Houston, R. (1952). Relationship of the electrocardiogram to various metabolic measures and crawl swim times. Unpublished master's thesis, University of Illinois.

This study was to determine the relationship between the energy metabolism measures of swimming, swimming times, and electrocardiogram measures. Thirty male varsity swimmers were tested for speed on the 100 and 440 yd. swims, oxygen intake, oxygen debt, and oxygen requirement, and electrocardiogram measures. The electrocardiogram measures were not closely related to the obtained metabolic measures. There was a significant relationship between the amplitude of the S wave and times for the 100 and 440 yd. swims. There was no significant relationship between any ECG items and the 5 criteria.

Hsieh, S. S., & Hermiston, R. T. (1983). The acute effects of controlled breathing swimming on glycolytic parameters. Canadian Journal of Applied Sport Science, 3, 149-154.

Six male swimmers swam 15 repeats of 200 yds. at about 80% of maximum with 30-45 sec. rest between repeats. One protocol allowed swimmers to breath freely; the other restricted them to one breath every 3.5 stroke cycles. Blood and expired air were analyzed before and after the sessions. No significant difference was found in any of the parameters analyzed, except for CO2 production in the 30 sec. immediately following the tests. Authors concluded that it is doubtful whether controlled breathing can be an effective training stimulus for swimmers.

Hunt, E. A. (1957). Electrocardiographic study of four champion swimmers before and after 100 metre swimming competition, Unpublished bachelors paper, University of British Columbia.

Hunt, E. A. (1961). Electrocardiogram study of champion swimmers. Unpublished masters thesis, University of British Columbia.

This was an electrocardiograph study of 20 champion swimmers before and after 110 yd. sprint swimming under competitive conditions. They were tested before exercise to determine resting blood pressures and pulse rates and to record resting ECG. The results showed individual variation in blood pressure and pulse rate. General trends were observed in the P-R interval, the ST segment and the T wave. Eighteen of 20 showed one or all of these variations, PR prolongation, T inversion, ST depression. It was concluded that such variations appearing after strenous competition in healthy young athletes would be indicative of functional adjustment of the myocardium to the

situation of physical and emotional stress.

Hunt, E. A. (1963). Electrocardiographic study of twenty champion swimmers before and after 110 yard sprint swimming competition. Journal of the Canadian Medical Association, 88, 1251-1253.

To record strain of actual swimming competition, 20 subjects were studied by electrocardiograms recorded after swim races of 110 yds. Blood pressure and electrocardiograms were taken at 3,6,9,12,15,20,25, and 30 min. after each race. Of the 20 cases studied, 18 showed at least one of the following abnormal findings. The PR interval was prolonged by at least 0.04 sec. and up to 0.10 sec. True ST depression and false ST depression was seen. A marked loss of T potential in all subjects or T inversion in 8 subjects was recorded. The causes for these alterations are considered physiological.

Hutchinson, B. (1971). Water direction perception and swimming. Swimming Technique, 8, (3), 768.

A review of Rebillard's thesis in which 19 swimmers were tested on an instrument to measure swimmers' ability to discriminate the direction of water pressure through extroceptors of the hand. The correlation derived from scores on this test and a competitive swimming index was significant.

Hutchinson, B. (1971). Effect of systematic weight training upon muscular efficiency as indicated by 100 yards of swimming performance. Unpublished master's thesis, University of Maryland.

It was the purpose of this study to investigate whether weight training improved muscular efficiency to a point where it would be of value in conditioning competitive swimmers. Two groups of competitive swimmers were used as subjects. One group of 7 trained by swimming and weight training, while the other group of 7 trained by swimming only. Time trials in the 100 yd. crawl stroke was considered indicative of muscular efficiency. They were given before and after the experimental period. Both groups swam faster in the 100 yd. crawl stroke after the experimental period. There was no significant difference between groups at the end of the experimental period.

Hutinger, P. W. (1970). Comparisons of isokinetic, isotonic, and isometric developed strength to speed in swimming the crawl stroke. Unpublished doctoral dissertation, Indiana University.

This study was to determine the effects of isokinetic, isotonic, and isometric developed strength on speed in swimming the crawl stroke, and to compare the strength developed through isokinetic method to other methods of strength development for an evaluation of transfer and specificity to swimming speed. Sixty-one male subjects were divided into one of three experimental groups or a control group. Twelve treatment sessions which included swimming training and strength development were given the experimental groups. No significant differences in treatment effects were found in swimming speed or

strength development among the groups. Excluding the isotonic exercise group, the other 3 groups had statistically significant increases in strength and corresponding increases in swimming speed for 100 yds. This was not a proportional increase. The isokinetic group had a significant increase in speed in the 50 yd. sprint.

Hutinger, P. W. (1971). The bradycardia reflex in competitive swimmers. Research Quarterly, 42, (3), 274-279.

Thirteen male competitive swimmers were tested on breath-holding in air and breath-holding in water with an electrocardiograph recorder. A significant difference was found between the two treatments. The bradycardia response was greater than that of poor swimmers reported in other studies, which may be interpreted as providing evidence supporting the existence of a marked perpheral vasoconstriction in man in response to face submersion in water. Constant exposure to submersion experienced by competitive swimmers did not mediate the bradycardia response.

Ikai, M. (1962). Electromyographic study of swimming. Revue de L'education Physique, 2.

Electromyographic studies were done on highly trained swimmers and those with little training in an effort to determine which group of muscles are concerned with each movement during various strokes in both good swimmers and poor swimmers.

Ikai, M., Ishii, K., & Miyashita, M. (1964). An electromiographic study of swimming. Research Journal of Physical Education, 7, 47-54.

Irving, R. N., Jr. (1973). Cardiovascular comparisons of four sport groups during concurrent competitive seasons. Swimming Technique, 10, 39-41.

This study was to examine 5 competitors each from among college teams engaged in swimming, wrestling, gymnastics, and basketball in order to compare the magnitude and direction of change in various aspects of cardiovascular condition between groups over a portion of the competitive season. Two cardiovascular measurements were made about 1 mo. apart on the Cameron Heartometer. Each sport group was ranked in 9 cardiovascular variables. Swimmers were significantly different from the other sport groups in 5 of the 9 variables.

Jackson, A., Jackson, A. S., & Frankiewicz, R. G. (1979). The construct and concurrent validity of a 12-minute crawl stroke swim as a field test of swimming endurance. Research Quarterly, 50, (4), 641-648.

Forty-two male collegiate swimmers were given 3 tests.
1. An endurance test had subject tethered swimming to exhaustion.

2. Crawl stroke count for 50 yds. 3. Twelve-minute crawl stroke swim for distance with total distance and distance covered each minute recorded. The data indicated the 12-minute swim a valid test for swimming endurance.

Jaeger, L. D. (1937). Resistance of water as a limiting factor of speed in swimming. Unpublished master's thesis, State University of Iowa.

This study was to determine the resistant affect of water in relation to subjects speed in swimming. Water and its resistance qualities in swimming were studied as to its affect in planeing, streamlining, under water and surface methods of progression. Fifteen subjects were towed 100 ft. and time taken for the last 60 ft. and timed swimming as fast as possible for 50 yds. and for 60 ft. and these times were compared with a resistance formula derived from the towing. Correlation between resistance and velocity was very low. Resistance varied with the type of body build.

Jenkins, D. H. R., Macleod, A., & Mackay, S. (1972). The electrocardiogram in swimmers. Journal of Sports Medicine, 12, 246-249.

Abnormalities of the electrocardiogram found in a group of young swimmers are described. These include marked sinus arrhythmia with nodal escape, atrioventricular conduction defects and incomplete right bundle branch block. One month of intensive training produced little change in the appearance of the electrocardiogram although the resting pulse rate fell significantly.

Jensen, C. R. (1964). Comparison of the dry body and wet body starts in swimming. Research Quarterly, 35, (1), 81-82.

Times for 60 yd. swims were compared when swimmer entered the water before the start, with times when swimmer did not enter water before the start. Under the conditions of this study, no differences were noted between the wet and dry body starts.

Jensen, C. R. (1963). Effects of five training combinations of swimming on weight training on swimming the front crawl. Research Quarterly, 34, (4), 471-477.

Sixty subjects were divided into 5 equal groups. Each group trained under one of the following training methods: 1) swimming 5 days a wk., 2) weight training 5 days a wk., 3) swimming 3 days a wk. and weight training 2 days a wk., 4) swimming 2 days a wk. and weight training 3 days a wk., 5) swimming and weight training 5 days a wk. The subjects were tested initially for speed and after each week of a 6 wk. training period. All 5 treatments resulted in significant swimming improvement, but none were significantly more effective than the others.

Jensen, R. K., & Tihanyi, J. (1978). Fundamental studies of tethered swimming.

In F. Landry & W. A. R. Orban (Eds.), Biomechanics of Sports and Kinanthropometry (pp. 143-148). Miami: Symposia Specialists Inc.

The purpose of this study was to use a modeling approach to estimate the loads on the upper extremity during the underwater phase of tethered and free swimming and to measure the horizontal impulse during front and back crawl and to relate these to free swiming performance. Ten female and 5 male swimmers were tested. Results suggest that tethered swimming should be an integral part of a swimming training program.

Jiskoot, J., & Clarys, J. P. (1975). Body resistance on and under the water surface. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp. 105-109). Baltimore: University Park Press.

The purpose of this study was to determine the body resistance on the water surface and 60 cm. under the water surface for a group of 43 male average to good swimmers. Testing was done in a towing tank. The total resistance while being towed under the surface is higher than that on the surface. Thus, it is preferable to swim on the surface instead of under the surface of the water.

Johnson, B. F. (1962). Relationship of hip strength and flexibility to breast stroke kick power. Unpublished master's thesis, Smith College.

This study was an investigation of the relationship between hip abduction flexibility and thigh adduction strength to the power obtained in the wedge and whip kicks used in breaststroke. Forty-nine females of intermediate level swimming ability were measured in hip abduction flexibility and thigh adduction strength. There was a significant difference between power of the wedge kick and the power of the whip kick. Flexibility was a definite factor in the production of power in the wedge kick. Flexibility had an inverse relationship to power in the whip kick.

Johnson, G. O., Thorland, W. G., Housh, T., Tharp, G. D., Refsell, M., & Knortz, K. (1982). Effect of a competitive season on the body composition of female university athletic teams. Medicine and Science in Sports and Exercise, Abstracts, 14, (2), 107.

Fifty-eight female athletes from 5 sports; swimming, track, vollyball, gymnastics, and basketball were studied to determine the effects of a seasons competition on changes in body composition. No pre-season differences between teams was found. Results indicate that changes in body composition across a season vary by sport.

Johnson, J. F. (1953). Effects of immersion and swimming movement on respiration and metabolism. Unpublished master's thesis, University of Illinois.

This study was to determine the effect of immersion and flutter

kicking on respiratory rate, depth and volume, respiratory quotient, gross oxygen intake, net oxygen intake, oral temperature and metabolic rate. Three graduate students had gas samples taken using the douglas bag techniques in recumbent position in and out of water of 76-79.5 degrees F. and while kicking in the water. Ventilation and gross 02 intake increased upon immersion and still more during kicking. Heat production increased during exercise in water. Regular swimming participation diminished respiratory and metabolic changes effected by passive immersion in cool water.

Johnson, T. C. (1975). Physiological changes in interscholastic competitive swimmers. Swimming Technique, 11, (4), 117-119.

This study was to investigate the effect of participation in an interscholastic swimming program on heart rate, mean arterial pressures during rest, exercise, and recovery as well as duration of exercise on a bicycle ergometer. Ten male varsity swim team members and 6 non-swimmers were tested over a period of 20 wks. of training. There were significant decreases in the resting rate, heart rate after 5 min. of exercise, and increase in riding time on the bicycle ergometer.

Johnson, T. F., & Wong, H. Y. C. (1961). Effect of exercise on plasma cholesterol and phospholipids in college swimmers. Research Quarterly, 32, (4), 514-521.

Varsity swimmers were studied over a period of 14 months with regard to the effect of a typical training and competitive collegiate swimming program on plasma cholesterol and phospholipids. Chemical analyses on blood cholesterol and phospholipids were made and compared for competitive and non-competitive seasons. It was found that the exercise used for conditioning varsity swimmers did not significantly lower blood cholesterol and phospholipids.

Jolicoeur, D., Ledoux, M., Helie, R., Brisson, G. R., & Peronnet, F. (1983). Iron status of female elite swimmers and ballet dancers. Medicine and Science in Sports and Exercise, Abstracts.

Ninty-five women ranging in age from 16 to 20 yrs. were examined to study the hematological status of women involved in strenuous training programs. Data show that food intake more than exercise is responsible for iron deficiencies reported in different athletic populations.

Jones, D. R., Alexander, J. F., & Stull, G. A. (1982). Changes in body composition and VO2 max in college women during a varsity swimming season. Medicine and Science in Sports and Exercise, Abstracts, 14, (2), 142.

Changes in body composition and VO2 max. associated with a varsity swimming season and relationships between training heart rate, perceived intensity, and distance swum were determined for 19 college-aged women. No changes in body composition were noted as a result of training.

Jorndt, G. T. (1973). The effect of exercise on ankle flexibility and on three swimming kicks. Unpublished doctoral dissertation, University of Utah.

The problem was to compare differences between two select swimming groups in ankle flexibility and in the propulsion rate over a distance of 25 yds., while performing 3 selected swimming kicks. Two groups of 38 boys with at least one yr. of competitve swimming experience were studied using 3 selected swimming kicks. They were the front flutter kick, the back flutter kick, and the dolphin kick over a distance of 25 yds. Four ankle stretching exercises were used to increase the range of motion of the ankle joint. No significant differences were found.

Kanitz, M. (1971). A comparison of water polo and swimming on the aerobic capacity, strength, and physical characteristics of varsity college swimmers. Unpublished doctoral dissertation, The Ohio State University.

The purpose of this study was to determine what effect a 7 wk. water polo program had on aerobic capacity, strength and physical characteristics of varsity college swimmers and to determine what effect a 7 wk. swimming program had on the same variables and to compare these two programs and to measure the aerobic capacity by treadmill running and to compare it to the aerobic capacity by free swimming. The physical characteristics of top varsity college swimmers did not change significantly due to either of the programs. Neither program was sufficient for significant strength gains except in hip extension. Both programs improved maximum aerobic capacity. No significant differences were observed in strength. Both brought a decrease in maximal heart rate and a lowering of the resting heart rate and brought about a faster return to normal heart rate following exercise.

Kanitz, M., & Bar-Or, O. (1974). Relationship between anthropometric, developmental and physiological parameters and achievement in swimming to 10- to 12-year old boys. Israel Journal of Medical Science, 10, 289.

This study was aimed at determining the relationships between success in swimming and some morphological and physiological variables in well trained boys. Participants were 37 swimmers from 16 swimming clubs, who reached the 1972 semifinal Israel championship competition in the 10- to 12-yr.-old division. They were divided into two groups on the basis of their swimming speed: group A the faster 17 and group B the slower 20. Testing methods included anthropometry, somatotyping, dental age, secondary sexual characteristics, lung functions, muscle strength and a determination of heart rate during a multistage bicycle ergometer test. Swimming times were positively correlated with dental age, height, arm span, lean body mass and vital capacity. These result indicate that body size and relative biological maturity are important factors affecting swimming success in fairly well-trained 10- to 12 yr.-old boys.

Karpovich, P. V. (1935). The effect of basketball, wrestling, and swimming upon the white blood corpuscles. Research Quarterly, 6, (2), 42-48.

Samples of blood were taken during trials from the varsity swimmers being tested. It was found that shorter distances (60 to 220 yds.) produced a lymphaytic phase, tending to a neutrophilic phase. Distances of 220 to 880 yds. gave a markedly neutrophilic phase.

Karpovich, P. V. (1939). Respiration in swimming and diving. Research Quarterly, 10, (3), 3-14.

It was found that respiratory movements interfere with propulsive movements and tend to decrease the speed of swimming. A general rule was found concerning respiration in swimming: Inhale before the body buoyancy is the least and exhale when it is the greatest. Also, in most of the strokes, exhaling should be done through the nose and inhaling through the mouth. Backstroke may be an exception. Very rapid inhaling may become inefficient for a proper lung ventilation.

Karpovich, P. V. (1934). The effect of oxygen inhalation on swimming performance. Research Quarterly, 5, (2), 24-30.

The effects of inhaling oxygen before performance was studied for 17 varsity swimmers. It was found that oxygen inhalation immediately followed by swimming increases the speed in the 100 yd. dash. Oxygen taken 4 to 5 min. before the 100 yd. swim had no noticeable effect upon the speed. Oxygen given in actual competition proved hardly worth while, because of the administration problems.

Karpovich, P. V., & Lemaistre, H. (1940). Prediction of time in swimming breast stroke based on oxygen conumption. Research Quarterly, 11, (1), 40-44.

The method used by Sargent for prediction of running time is applied to breaststroke swimming. By testing an individual's maximum oxygen intake, maximum oxygen debt and oxygen requirement for various speed, it was possible to predict swimming times up to 1320 ft., while the testing distance never exceeded 180 ft. This investigation shows that an improvement in swimming can be made through an increase in oxygen intake, oxygen debt and improved efficiency of the stroke. Capacity for oxygen intake and debt will be increased through intensive swimming.

Karpovich, P. V., & Millman, N. (1944). Energy expenditure in swimming. American Journal of Physiology, 142, 140-144.

Energy costs of swimming crawl, back, breast, butterfly and side stroke at speeds greater than 2 ft/sec. were found on 24 subjects of both sexes. Swimming at speeds higher than 2 ft/sec. was considered a vigorous exercise

because metabolism rose more than 10 times the basal rate. At speeds beyond 2 ft/sec. metabolism may be more than 100 times higher than basal. Unskilled swimmers expend from 2-5 times as much energy as skilled swimmers. Fluctuations between individuals is greater for the lower speeds than for the higher ones. Strokes arranged in order of increasing energy cost: crawl backcrawl, breast and side. This relationship was true for higher speeds also. The butterfly was found to be the least economical of the 5 strokes under 2.5 ft/sec. Above this speed it becomes more efficient than the side stroke and at 3 ft/sec. is more economical than the breaststroke. Greater fatiguing effect of the butterfly was attributed to local fatigue of the shoulder girdle muscles. No sex difference in relative cost of swimming was observed.

Kasch, F. W. (1977). Physiological changes with swimming and running during two years training. Proceedings of the 24th Annual Meeting of the American College of Sports Medicine, Chicago.

Key, J. R. (1962). Relationships between load and swimming endurance in humans. Research Quarterly, 33, 559.

This study was to investigate the effect of load on swimming endurance in humans. Twenty male subjects between the ages of 17 and 24 swam in a vertical to semi-vertical position until exhausted or until an hour had elapsed. This was done with loads of 0,2,4,6,8,10,15,20,25, and 30% of the body weight. The lead used as a weight was placed around the waist of the swimmer. The times were recorded at each load and the means determined and plotted. The relationship between load and endurance was close and curvilinear. Heavier individuals were at a slight disadvantage in this test which used percentage of body weight as a measure of load. Among good swimmers a load of 4% of the body weight did not decrease swim time appreciably, while a load of 30% reduced swim time to a matter of seconds.

Kimura, Y., Yeater, R., & Warner, J., Jr. (1985). Simulated swimming: A useful tool for assessing the VO2 max of swimmers in the laboratory. Medicine and Science in Sports and Exercise, 17, (2), 267.

This study was designed to develop a simulated swimming exercise so that VO2 max. could be assessed on swimmers in the laboratory setting. Subjects assumed a prone position on an incline bench and performed arm cranking on a Monark rehab trainer while performing a flutter kick against tension supplied by elastic cords. This test was compared to 4 VO2 max. tests; treadmill running, tethered swimming, bicycle ergometry and arm cranking. Eleven male varsity swimmers were measured on all tests. There was no significant differences in VO2 max between simulated swimming and tethered swimming. Treadmill running and bicycle ergometry VO2 were significantly higher and arm cranking was lower. The simulated swimming test was found reliable and may be used as effectively as tethered swimming to assess the VO2 max of swimmers in a laboratory setting.

King, D. S., Sharp, R. L., Costill, D. L., & Snyder, A. C. (1983). Power characteristics of world-class swimmers: Relationship to freestyle swimming performance. Medicine and Science in Sports and Exercise, Abstracts, 15, (2), 161.

This study examined arm power in 53 male and 48 female freestyle competitors at the 1982 U. S. National swimming championships, and the relationship between power and swim performance in these elite swimmers. There was no significant relationship between peak power, mean power, or optimal speed setting on the biokinetic swim bench and freestyle swim performance.

Kingston, M. (1961). Effects of two training programs on swimming speed, physiological efficiency and strength of college women. Unpublished master's thesis, University of North Carolina Womens College.

This study was to determine the effects 2 different training programs of swimming would have on abdominal strength, leg strength, shoulder strength, vital capacity, oxygen consumption, cardiovascular efficiency, and speed in ming on 12 female college swimmers. They were divided into 2 groups. The exercise swimming group participated in exercise workouts 3 times weekly during the first mo. and in swimming workouts 3 times weekly during the second mo. The swimming group participated in swimming workouts 3 times weekly for the duration of 2 mo. The swimming group had a statistically significant faster mean swimming speed. No significant differences were found in vital capacity. The total group had an increase in oxygen consumption which was statistically significant. The total group had an increase in cardiovascular efficiency which was statistically significant. Both groups had significant gains in abdominal and leg strength.

Kipke, L. (1978). Dynamics of oxygen intake during step-by-step loading in a swimming flume. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 137-142). Baltimore: University Park Press.

This investigation was done to determine respiration changes during swimming. Testing was conducted in a flume using step-by-step loads and varying water velocities. Findings revealed that respiration is appreciably affected by swimming technique; because respiratory frequency, depth, and volume change from one technique to another. Oxygen intake also changes. It was concluded that a swimmer does not completely utilize his full oxygen intake capacity during competition.

Klein, W. C. (1939). Tests for prediction of body resistance in water. Unpublished master's thesis, State University of Iowa.

Tests were given to 59 swimmers to determine their resistance in the water from variables which might be applied practically. From the resistance, measured by pulling the subjects through the water, a coefficient of resistance was computed. This was used as the criterion variable and obtained by curve

fitting. The distance that the swimmer covered in the push-off on the surface and the weights were found to be the most practical measures of resistance.

Klissouras, V. (1967). Energy metabolism in swimming the dolphin-butterfly stroke. Unpublished doctoral dissertation, Springfield College.

This study was to analyze the energy metabolism of subjects while they swam using the dolphin-butterfly stroke. To analyze the relationship between oxygen consumption and the speed of subjects and to determine mechanical efficiencies of subjects when they swam at different speeds while using the full stroke, legs alone and arms alone as well as to determine the energy expenditure of the subjects while they performed swimming turns were also objectives of this study. Six college swimmers who had experience in the dolphin-butterfly were used as subjects and they were tested on an open-circuit method for collection of expired air. The O2 consumption while swimming with the full stroke, arms alone or legs alone increased exponentially with an arithmetical increase in swimming velocity. At competitive speeds, swimming with kick alone requires more energy than swimming at the same velocity with arms alone or full stroke. The mechanical efficiencey increased as the velocity of swimming increased. At maximal speeds swimming with the dolphin-butterfly was slightly more efficient than swimming with arms only.

Klissouras, V. (1968). Energy metabolism in swimming the dolphin stroke. Arbeitsphysiologie, 25, 142-150.

Refer to Klissouras, V. (1967).

Knott, J. (1971). The immediate effect of swimming and track competition on blood ph values. Unpublished master's thesis, Eastern Illinois University.

This study was to investigate the changes associated with blood ph and different exercise work loads during competition. Finger tip blood samples were taken from 33 male subjects from the varsity swimming and track teams. A drastic ph decrease occured after exercise. The lower mean post exercise ph values and greater ph changes occured after events of short duration and high intensity. Relatively high positive correlations were found between the duration of the track event and the post exercise ph values and ph changes. The track events produced greater mean ph changes and lower mean post exercise ph values than did comparable swimming events.

Knowlton, R. G., Swaka, N. M., Miles, D. S., & Critz, J. B. (1978). post competition blood lactic acid concentrations in collegiate swimmers. Research Consortium Paper, American Alliance of Health, Physical Education, and Recreation.

Kong, M. H. (1954). Physical fitness improvement of varsity swimmers from a season of training. Unpublished master's thesis, University of Illinois.

This study was to determine the physical fitness improvements of 16 varsity swimmers from training. A battery of 34 test items was given to from 4 to 16 subjects at both the beginning and end of the season. The season of training for competitive swimming improved organic fitness considerably, improved motor efficiency significantly, but did not affect the overall measure of physique according to the measurements taken.

Kornecki, S., & Bober, T. (1978). Extreme velocities of a swimming cycle as a technique criterion. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 402-407). Baltimore: University Park Press.

The purpose of this study was to verify the ratio of relative deviations between maximum and mean velocities within the stroke cycle to the mean velocity at a given distance by finding the relationship between this index and the time necessary to swim a given distance using one butterfly stroke. Swimmers movements and their relationship with changes in this index were also analyzed. Twenty-two Polish butterfly swimmers were filmed for analysis. Efficiency and economy of technique were characterized by: shortened duration of the stroke cycle, the push pack phase, and the arms' recovery phase; high minimum velocity within the stroke cycle; and a relatively small range of hip movement throughout the stroke cycle.

Krizan, T. F. (1948). Comparison of Olympic and varsity swimmers of physical fitness characteristics. Unpublished master's thesis, University of Illinois.

The purpose of this study was to compare measurements of physical fitness characteristics of the 1936 American Olympic swimmers with the candidates for a university varsity swimming team. The highest relationship between the groups of swimmers were circulatory, flexibility, respiratory, and adipose tissue measurements.

Kruchoski, E. P. (1954). A performance analysis of drag and propulsion in three selected forms of the back crawl. Unpublished doctoral dissertation, State University of Iowa.

Lavoie, J. M., Leger, L. A., Leone, M., & Provencher, P. J. (1985). A maximal multistage swim test to determine the functional and maxiaml aerobic power of competitive swimmers. Journal of Swimming Research, 1, (2), 17-22.

The purpose of this experiment was to develop a useful test to predict the functional and maximal power in competitive swimming. It consisted of establishing a relationship between swim velocity and 02 consumption. These items were measured on 14 competitive swimmers and showed an acceptable predicting measure for maximal power.

Lavoie, J. M., Taylor, A. W., & Montpetit, R. R. (1981). Physiological effects of training in elite swimmers as measured by a free swimming test. Journal of Sports Medicine, 21, 38-42.

The training response of 11 Canadian National swimmers (6 males and 5 females) was investigated. These swimmers were tested before and after a 6 mo. training period for (1) maximal aerobic power , (2) maximal heart rate, and (3) blood lactate concentrations, using a free swimming test. The training consisted of a daily swim distance of from 8-18000M. VO2 max. increased from 4.11 to 4.44 l/min. and from 3.15 to 3.37 l/min. for male and female groups respectively. Maximal heart rate decreased significantly for both groups of swimmers. Cardiovascular adaptations do occur in elite athletes during severe training.

Lee, L. W. (1965). Practices in conditioning of competitive swimmers. Unpublished master's thesis, Springfield College.

This questionnaire study was undertaken to gather information about the in water and out-of-water conditioning programs in use by collegiate swimming coaches throughout the United States and to compare information concerning the various training methods employed by these coaches to reach some conclusions which may serve as a basis for determining improved training procedures for the future. Replies from 158 coaches , 55% were received. Data is summarized into 48 separate statements of existing practices. Eight conclusion were drawn from the data.

Leighton, J. R. (1957). Flexibility characteristics of four specialized skill groups of college athletes. Archives of Physical Medicine and Rehabilitation, 38, 24-28.

Fifty swimmers of at least 2 yrs. competitive experience were measured on 30 tests of flexibility. A high flexibility performance ability on 25 of the 30 tests was shown. They did not show high ability on shoulder flexion and extension, hip adduction and abduction, trunk flexion and extension, or on trunk rotation tests in relation to the other atheletes measured.

Le Pere, C. B. (1972). Cardiovascular and metabolic response of skilled and recreational college age swimmers to running and swimming. Unpublished doctoral dissertation, University of Idaho.

Fourteen skilled and 15 recreational swimmers were given a series of tests for oxygen uptake on the treadmill and while tethered and free swimming. The capacity for oxygen uptake in swimmers while swimming may be a function of muscular endurance specific to swimming and efficient stroke technique. The status of training could be evaluated by estimation of oxygen uptake. Swimmers did not reach the same levels of oxygen uptake swimming as they did while running on the treadmill. All water tests significantly separated skilled from recreational swimmers.

Lewillie, L. (1971). Quantitative comparison of the electromyogram of the swimmer. In L. Lewillie & J. P. Clarys (Eds.), Proceedings of the First International Symposium on Biomechanics in Swimming (pp. 155-159). Brussels: Universite Libre de Bruxelles.

The electromyogram of the swimmer is recorded with an ampli transmitter, a receiver and a magnetic recorder.

Lewis, H. B. (1941). Preliminary study of the relationship of the factors of propelling force and body build to the ability of women to develop speed in swimming the crawl stroke. Unpublished master's thesis, University of Oregon.

This study was to determine whether or not propelling force and body build had any effect on the ability of 61 college females to develop speed in swimming the crawl stroke over distances of 60 and 120 ft. Age, height, weight, and body build seemed to have little relationship to propelling force or to the criteria of speed for 60 and 120 ft.

Lietuvietis, K. (1958). Effects of isotonic and isometric leg exercises on selected swimming kicks. Unpublished master's thesis, State University of Iowa.

Forty-seven female volunteers from life saving and swimming classes were divided into 3 groups to determine the effect of isotonic and isometric leg exercise on ability to go through the water with the front and back flutter and sissors kicks. The 16 subjects in the isometric group exercised legs before class by means of 6 sec. maximum muscle contractions against resistance. The isotonic group did progressive resistance leg exercises before class. The 18 in the control group did no exercises. All subjects were tested and re-tested on swimming kick and strength. The isometric group showed statistically significant strength gains.

Life, M. L. (1964). Effects of supplementary isometric exercises with swimming and golf on selected physiological factors of college women. Unpublished doctoral dissertation, Louisiana State University.

This study was to look at the effects of supplementary isometric exercises with swimming and golf on muscular strength, physical fitness and cardiovascular efficiency of college women. Ninty-six college women composed 4 groups. One participated in intermediate swimming and an isometric exercise program. Group 2 participated in beginning golf and an isometric exercise program. Group 3 particapated in intermediate swimming with no exercises. Group 4 participated in beginning golf and no supplementary exercises. Subjects were tested on the Rogers physical fitness index test and the cardiovascular efficiency test for girls and women. Physical fitness can be improved by participation in intermediated swimming, beginning golf, and a combination of either of these activities and an isometric exercise program.

No difference was found in the effectiveness of intermediate swimming and beginning golf in improvement of physical fitness. Addition of isometric exercises to intermediate swimming did not increase the effectiveness of these activities. Intermediate swimming improves cardiovascular fitness of college women. Intermediate swimming with isometric exercises will improve the cardiovascular efficiency of college women.

Liljestrand, G., & Lindhard, J. (1919). Concerning the minute volume of the hearts of swimmers. Scandinavian Archieves of Physiology, 39, 64-77.

Liljestrand, G., & Stenstrom, N. (1919). Studies of the physiology of swimmers. Scandinavian Archieves of Physiology, 39, 1-63.

Lipke, L. (1974). Differences in the oxygen intake values determined during free swimming and during tests on the bicycle ergometer. Third Medico Scientific Conference of FINA, Barcelona.

Lueft, R. J. (1958). The effects of warming-up on swimming speed. Unpublished master's thesis, Pennsylvania State University.

A study of 49 subjects on the effects of warming up on swimming 50 yds. The warm up was a formal type exercise on land as well as doing a 50 yd. crawl stroke in the water. The mean times for the warm up trials were slightly faster than those for non-warm up trials. Difference was not significant however.

Luetkemeier, M. J. (1978). The effect of endurance swimming on the cardio-respiratory fitness levels of sedentasry middle-aged men and women. Unpublished master's thesis, Ball State University.

Luther, C. C. (1952). Relationship of selected swimming tests with swimming time and metabolic measures. Unpublished master's thesis, University of Illinois.

This study was to determine the relationships between recorded times for the 100 and 440 yd. swims, metabolic measures collected during swimming and recovery, and selected swimming tests. Forty-one varsity swimmers were tested for both 100 and 440 yd. swims, gross oxygen intake, gross oxygen debt, and oxygen requirement. Ten variables were compared to these measures. the arm stroke was more important in swimming shorter distance and legs more important in long distance swims. A 24 ft. glide showed the

most significant relationship with the criteria. Underwater swimming appears to be a measure of endurance condition.

Mader, A., Heck, H., & Hollmann, W. (1978). Evaluation of lactic acid anaerobic energy contribution by determination of post-exercise lactic acid concentration of ear capillary blood in middle distance runners and swimmers. In F. Landry & W. Orban (Eds.), Exercise Physiology (pp. 187-199). Miami: Symposia Specialists, Incorporated.

A report on the technique used by the East and West Germans to determine the optimum training and conditioning pace for for each athlete involved in an activity utilizing a constant pace for the duration of his competition and lasting longer then 30 sec. By measuring the milimoles per liter of lactic acid in the blood following this it was shown that the aerobic-anaerobic threshold is at a level of activity which produces 4 milimoles of lactate per liter throughout the blood stream.

Magel, J. R. (1971). Comparison of the physiologic response to varying intensities of submaximum work in tethered swimming and treadmill running. Journal of Sports Medicine, 11, 203-212.

Twenty-six trained college swimmers were subjects in a study comparing the physiologic response to a progressive work task during treadmill running and tethered swimming. The response of VO2 to increasing work was essentially linear for all subjects in both forms of exercise. Breaststroke swimmers demonstrated significantly lower VO2 at similar work levels during submaximal swimming when compared to other style swimmers. Heart rate response to both running and swimming appears relatively linear to near maximum work levels for all swimmers. Pulmonary ventilation increased linearly with increases in VO2 during running and swimming. Significantly lower cardiac response during swimming was attributed to the change in body position from the upright to the prone or supine position while swimming as well as the more favorable condition for heat dissipation during work in water as compared to work in air.

Magel, J. R., & Andersen, K. L. (1969). Pulmonary diffusing capacity and cardiac output in young trained Norwegian swimmers and untrained subjects. Medicine and Science in Sports, 1, (3), 131-139.

Pulmonary diffusing capacity and cardiac output were measured during work increments on a bicycle ergometer up to the maximum oxygen uptake in trained swimmers and in healthy untrained subjects from Norway. At rest and throughout the entire range of exercise, pulmonary diffusing capacity values were significantly higher in trained swimmers than in untrained. Maximal values for pulmonary diffusing capacity in trained swimmers averaged approximately 51% above resting level, while the increase was significantly less (35%) for untrained subjects. Swimmers demonstrated significantly higher lung volumes and functional lung capacities than untrained subjects, suggesting that the larger lung volumes of trained swimmers may provide for potentially greater expansion of the pulmonary capillary bed during exercise.

Magel, J. R., & Faulkner, J. A. (1967). Maximum oxygen uptakes of college swimmers. Journal of Applied Physiology, 22, 929-933.

The maximum oxygen uptake of 26 trained college swimmers was measured during treadmill running, tethered swimming, and free swimming. No significant differences were observed between the mean oxygen uptakes during treadmill running and during tethered swimming. However, the mean aerobic capacity while swimming free was significantly greater than the mean obtained swimming tethered, possibly due to a training effect. The pulmonary ventilation and respiratory exchange were significantly lower and oxygen extraction was significantly higher swimming tethered than running.

Magel, J. R., Foglia, G. F., McArdle, W. D., Gutin, B., Pechar, G. S., & Katch, F. I. (1975). Specificity of swim training on maximum oxygen uptake. Journal of Applied Physiology, 38, 151-155.

This study was designed to evaluate the specificity-generality of the cardiorespiratory adaptation to swim training. Fifteen male college age recreational swimmers utilized interval swim training procedures for 10 wks. of training. Maximum physiological measures were determined before and after the training on treadmill running and tethered swimming tests. Fifteen control subjects were also tested. The swimming group significantly increased their VO2 max. and swim time and decreased max. heart rate. There were no differences when evaluated by the treadmill running test. Results demonstrated the specificity of the cardiorespiratory adaptation to swim training.

Magel, J. R., McArdle, W. D., & Glaser, R. M. (1969).Telemetered heart rate response to selected competitive swimming events. Journal of Applied Physiology, 26, 764-770.

Heart rate response prior to, during, and in recovery from selected competitive swimming events was determined in 7 male members of a varsity swimming team by means of radiotelemetry. The swimming events studied were the 50, 100, 200, 500, and 1000 yd. swims. The heart rate increased rapidly during the initial stages of each race and then climbed progressively toward maximum as the race proceeded. Several plateaus in heart rate and swimming speed were reached during the 500 and 1000 yd. events. The longer swimming events tended to elicit higher peak heart rates than the shorter sprint events. Recovery from the 50 yd. event was more rapid than any of the longer distances. In an attempt to control for the effect of work duration when comparing heart rates running and swimming, all subjects ran distances comparable in time to those they had swum. The pattern of heart rate response in running was essentially similar to swimming, but the magnitude of the response was greater in all running events. The maximum heart rates during running were significantly greater than those obtained during swimming for a similar time period.

Maglischo, E. W., Maglischo, C. M., Smith, R. E., Bishop, R. A., & Hovland, P. N. (1984). Determining the proper training speeds for swimmers. Journal of Swimming Research, 1, 32-38.

The purpose of this study was to to determine the effect of a season of competitive swim training on the swimming speeds and heart rates required to produce certain blood lactate concentrations. Blood samples were collected from 6 male college swimmers on three different occations during 6 wks. of training. Immediate post-swim heart rates were graphed opposite the blood lactates they produced. An average increase of 16% was required to produce a blood lactate concentration of 2 MM/l from the beginning to the end of the training period. At the 4 MM/l level the required increase in effort between tests was 13.3. An average increase in post-exercise heart rates of 38 BPM was required to produce a blood lactate concentration of 2 MM/l from the beginning to the end of the test period. All of these results were significant. Increases at 12 MM/l did not attain significance. Suggestions were presented as to the optimum speeds and heart rates for improving the aerobic and anaerobic capacities of competitive swimmers.

Mana, K. (1954). Effects of different warm up methods on the times for swimming the one-hundred yard crawl. Unpublished master's thesis, University of Iowa.

This study was made on 13 varsity swimmers to compare the effectiveness of 4 different warm-up methods on swimming 100 yd. crawl. Calisthenics hot showers, and 800 yd. swim were used as warm-up. There were no significant differences between any of the warm-up methods used.

Marino, M. W., Solomons, C. C., Monoz, R., et al. (1980). Prediction of swimming speed from platelet purine metabolism. Medicine and Science in Sports, 12, 99.

Martin, J. L. (1973). Relationship of selected biological rhythms to performance of competitive swimmers. Unpublished doctoral dissertation, University of Utah.

This study was to determine the relationship between selected biological rhythms and performance of 31 varsity swimmers. Data were tabuated by use of the Thommen biomathematic charts, which provided a method to determine the relationship of biological rhythms to performance. When the physical and emotional cycles were in oscillation synchronization, a close relationship between performance and biological rhythms occurred. When the emotional and intellectual biological rhythms were in oscillation synchronization, very few relationships to performance could be determined. When the physical and intellectual biological rhythms were in oscillation synchronization, no relationship to performance was observed.

Martinez, R. H. (1961). Physiologic effects of swimming 100 yard races in water of five temperatures. Unpublished doctoral dissertation, State University of Iowa. Reprinted (1961). The 64th Proceedings of College Physical Education Association, 108-112.

A stationary swimming procedure was used that duplicated subjects heart rate, minute-volume, rectal temperature and energy metabolism as close as possible to conditions following 100 yd. races against time in a pool. Findings indicated that well-trained swimmers may expend less energy during 100 yd. races in water with a temperature of 79 degrees F. than during 100-yd. races with lower temperatures of 69 or 74 degrees F. or higher temperatures of 84 or 89 degrees F.

Marx, E. I. (1952). Effect of a dietary supplement on varsity swimmers. Unpublished master's thesis, University of Illinois.

This study was to determine the effects of dietary supplement in the form of wheat germ oil on the physical fitness of 14 varsity swimmers. Each subject received 20 capsules a day, every day, 7 days a wk. The experimental group had capsules of wheat germ oil and vitamin E while the control group had capsules of equal amounts of vitamin E and cottonseed oil for 45 days. Those receiving wheat germ oil increased the gross body reaction time.

McArdle, W. D., Glaser, R. M., & Magel, J. R. (1971). Metabolic and cardiorespiratory response during free swimming and treadmill walking. Journal of Applied Physiology, 30, 733-738.

The VO2 and telemetered HR and ventilatory response during free swimming and walking were studied on 5 male trained college swimmers. In the swimming test the work was altered by incrasing the stroke frequency by means of an electronic pacing device. VO2 was essentially linearly related to work intensity in both tests. The maximum ventilatory equivilant and breathing rate were significantly higher in walking than in swimming. During submaximal work oxygen extraction was generally higher in swimming with HR lower in swimming throughout the range of work. The energy cost of swimming at various speeds is presented in relation to previously reported data.

McArdle, W. D., Magel, J. R., Delio, D. J., Toner, M., & Chase, J. M. (1978). Specificity of run training on VO2 max and heart rate changes during running and swimming. Medicine in Science and Sports, 10, 16-20.

McCormic, A. L. (1956). The effects of a progressive resistance exercise on the upper extremities and its effects on 100 yard swimming performance. Unpublished master's thesis, Michigan State University.

To evaluate the influence of progressive resistance exercise on upper extremities and its effects on 100 yd. crawl stroke performance, two groups of 5 subjects were matched on total times for 100 yd. crawl stroke. The experimental group participated in a weight training program in addition to a swimming training program identical to the control groups. Weight training had no deleterious effects on sprint swimming times.

McCurdy, J. H., & Larson, L. A. (1940). Validity of circulatory-respiratory measures as an index of endurance condition in swimming. Research Quarterly, 11, 3-11.

This study examines the relationship between 46 circulaory respiratory measures and 440 yd. swimming times on 20 swimmers. A shorter battery of 22 measures was also given to 40 Olympic swimmers and 138 infirmary patients as controls. An equation, including measures of standing diastolic pressure, 20 sec. breath-holding, vital capactiy and sitting pulse pressure divided by sitting systolic pressure was found a valid index of functional conditioning for endurance swimming. It yields a predictable time for swimming the 440 yds. among the mechanically efficient swimmers, but not for the Olympic swimmers.

McElveen, G. W., Bell, G. H., Herbert, W. G., & Sebolt, D. R. (1985). Physiological responses to maximal exercise in tethered swimming, leg cycle ergometry, and simultaneous arm and leg work on an air braked ergometer among swimmers. Medicine and Science in Sports and Exercise, 17, (2), 267.

Physiological responses to maximal exercise on a tethered swimming apparatus, leg cycle ergometer, and an air braked simultaneous arm and leg work ergometer were compared to determine whether tethered swimming responses could be predicted from the other tests among 15 male recreational swimmers. No significant differences were observed between the tethered swimming and the leg cycle ergometer data. These results indicate that among recreational swimmers maximal exercise on one elicites accurate estimates of physiological responses on the other, but the arm and leg ergometer overestimated responses from the tethered swimming.

McMurray, R. G. (1969). Effects of body position and immersion on recovery after swimming exercise. Research Quarterly, 40, (4), 38-42.

Heart rates were recorded for 3 min. for 8 collegiate swimmers after a 5 min. swim with a pre-determined work load. After each 5 min. swim, one of the 4 recovery positions (erect and supine on the deck, motionless and swimming in the water) was assumed. After allowance for recovery, the subject was timed for a 200 yd. swim. no significant differences were noted when comparing the recovery heart rates or the 200 yd. times for the four conditions. Subjectively, the swim was felt to be harder when recovery was completed in an erect or supine postition than after light exercise in the water.

Meleski, B. W., & Malina, R. W. (1985). Changes in body composition and physique of elite university-level female swimmers during a competitive season. Journal of Sports Science, 3, 33-40.

Fifteen female college swimmers on a national-championship team were tested for body composition over a 24 wk. period of a competitive season. Significant changes in body composition were noted during the most intensive training part of the season. Body weight, absolute and relative fatness, all skinfold measurements used in the study, and calf circumference all decreased. During the same period, density and lean body mass increased significantly. During the second half of the season, weight and relative fatness increased significantly, while body density and the triceps skinfold decreased. Over the course of the study, arm girth increased significantly, while biceps and triceps skinfold decreased significantly, suggesting a specific hypertrophy of arm muscle mass.

Millard, M., Zauner, C., Cade, R., & Reese, R. (19850. Serum CPK levels in male and female world class swimmers during a season of training. Journal of Swimming Research, 1, (2), 12-16.

The effect of a season's training on serum creatine phosphokinase (CPK) was examined in 10 male and 10 female elite swimmers. During each of 5 mon. a venous blood sample was taken immediately following a swim workout and then about 45 min. later. to determine serum CPK. Resting CPK values for males were significantly higher than females during months 1 and 4, but did not differ in months 2,3 and 5. It was concluded that swim training increases serum CPK more in males than in females except during the taper.

Miyashita, M. (1971). An analysis of fluctuations of swimming speed. In L. Lewillie & J. P. Clarys (Eds.), Proceedings of the First International Symposium on Biomechanics in Swimming (pp. 53-58). Brussells: Universite Libre de Bruxelles.

Making use of a new apparatus, fluctuations of speed in swimming speed were measured on 8 trained swimmers and 1 untrained swimmer. Results indicate that swimming speed varies according to a single cycle of both arms. There is no definite relationship between movements of the arms and the moment when the highest speed is attained.

Miyashita, M. (1975). Arm action in crawl stroke. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp. 167-173). Baltimore: University Park Press.

This study consisted of three experiments. The first concerned the stroke time in the crawl in relation to age and performance. The second involved the relation between arm-pull strength and speed of swimming with arms alone. Thirdly, the oxygen requirement for swimming 25M with arms alone was determined for 4 swimmers with different levels of muscular strength and swimming technique. Findings support the correlation between swimming performance and muscular strength and/or maximal oxygen intake.

Miyashita, M. (1978). Method of calculating overall efficiency in swimming crawl stroke. In F. Landry & W. A. R. Orban (Eds.), Biomechanics of Sports and Kinanthropometry (pp. 135-142). Miami: Symposia Specialists Incorporated.

A method for evaluating overall efficiency in swimming was proposed using swimming performance and maximal power of the energy yielding process. Differences in performance between Japanese and Caucasian swimmers depended upon differences in the maximal power of energy yielding processes.

Miyashita, M., Hayashi, Y., & Furuhashi, H. (1970). Maximum oxygen intake of Japanese top swimmers. Journal of Sports Medicine, 10, 211-216.

The VO2 max. of 27 male and 17 female top swimmers of Japan were measured during treadmill running. Maximum oxygen intake for male swimmers was 4.9 L. per minute maximum and 3.33 L. minimum. For females these were 3.32 L. maximum and 2.60 L. minimum. Those maximum VO2 of Japanese top swimmers were from 30-40% more than those of Japanese youth and about 10% less than those of American and Swedish swimmers.

Montpetit, R. R., & Cazorla, G. (1982). The influence of the force of gravity and body drag on the energy cost of swimming the front crawl. The V International Congress on Biomechanics and Medicine in Swimming.

The relative energy costs of overcoming gravity and overcoming body drag were studied on 10 national level Canadian swimmers. An extra load was added to the sinking force at each swimmers' center of volume, and the O2 cost of overcoming the additional load measured. Results showed that energy contributions to overcome drag increased linearly up to a velocity of 1.27 m/sec. thereafter, the curve was asymptotic. It was concluded that the relative energy cost of maintaining a horizontal body position is independent of speed.

Morehouse, L. F. (1941). The respiratory habits of trained swimmers during the start of a race. Research Quarterly, 12, (2), 186-188.

The respiratory habits of 6 varsity swimmers were studied with the use of a pneumograph. It was found that before the command, "take your marks," trained swimmers either breathed normally or used forced respiration. While the swimmers maintained their balance in the start position waiting for the pistol shot, the breath was held after a normal inspiration. A deep inspiration was made and held as the swimmers left the blocks.

Mostyn, E. M., Helle, S., Gee, J. B. L., Bentivoglio, L. G., & Bates, D. V. (1963). Pulmonary diffusing capacity of athletes. Journal of Applied Physiology, 18, 687-695.

This study measured pulmonary diffusing capacity of 5 swimmers of average ability and 8 championship swimmers in training as well as other groups of athletes and non athletes. Champion swimmers were found to have significantly higher steady-state pulmonary diffusing capacities than those of normal subjects of comparable age at the same exercise level. This results from a larger than normal pulmonary capillary blood volume. Champion swimmers have a need of high DL since they must be able to transfer larger volumes of oxygen across the lung when the alveolar PO2 has fallen to low levels.

Mowrer, N. J. (1962). Some effects of a program of distance swimming upon selected physical fitness measures. Unpublished master's thesis, University of California.

To investigate the "swim and stay fit" program, 59 female college age subjects were put in one of 3 groups to determine effects a program of distance swimming would have on physical fitness measures. The experimental group of 22 swam 24 quarter mile swims over an 8 wk. period. A class instruction group of 16 swam in regular intermediate swim classes. A control group of 21 had no physical activity for this period. All subjects were measured in breathing capacity, abdominal strength, circulatory-respiratory efficiency and body weight. The experimental group improved significantly in breathing capacity and in circulatory-respiratory efficiency, but not in abdominal strength. Class instruction group improved in all measures except weight change. Controls did not change.

Moyle, W. J. (1936). Study of speed and heart size as related to endurance in swimming. Unpublished master's thesis, State University of Iowa.

Purposes of this study were to study the proportionate heart size in relation to endurance in swimming the crawl stroke; the relative contribution of arm stroke & leg stroke to whole stroke and their relationship to endurance; and to study effect of speed in relation to endurance. Twenty varsity swimmers were tested. A low relationship between heart size and endurance was found; not much relationship between speed and endurance; and a moderate to high correlation between velocity squared of the whole stroke, arms alone, and legs alone.

Muido, L. (1946). The influence of body temperature on performance in swimming. Acta Physiologica Scandinavica, 12, 102-109.

An experiment on the influence of preliminary exercise and body temperature rise on performance. Three subjects jogged for 10 min., had 10 min. heavy work on the bicycle ergometer, hot showers, turkish baths, radio diathermy, and cold baths at different time intervals. Conclusions: A given distance could be swum in a shorter time following a warm up. Both active warm up and passive warm up had the same beneficial effect. Increased blood temp. was more essential for improved performance than increased muscle temp. The warming influence was of 60-80 min. duration.

Murray, J. L. (1962). Effects of precisely prescribed progressive resistance exercises with pulley weights on speed and endurance in swimming. Unpublished master's thesis, Pennsylvania State University.

This study was to compare the effects of a training program in swimming consisting of precisely prescribed progressive resistance exercises with pulley weights plus swimming practice, with a program of swimming practice only. Thirty-one male university students were divided into a control and an experimental group from results of tests. The experimental group practiced weight training with a special pulley-weight apparatus to increase strength and endurance of specific back-crawl stroke swimming muscles. Both programs resulted in significant improvement in swimming speed, swimming speed with arms, swimming speed with legs, and swimming endurance. The weight training exercises plus swimming practice had no greater effect on swimming speed in any way, or swimming endurance than the training program of swimming practice only.

Myhre, L. G., Counsilman, J. E., & Pettinger, J. D. (1970). The rate of blood lactate accumulation in world class swimmers competing at low and high altitudes. Abstracts of Research Papers, AAHPER Convention, Seattle.

Three world class swimmers, two young men and one young woman were selected as subjects. Control measures at an altitude of 850 ft. were followed by repeating the same experiment at 7350 ft. less than 2 weeks later. The experiments included in this study were as follows: 1) All-out performance (400 m. freestyle), and 2) Sub-maximal performance (100 and 200 M. freestyle swum at 400 M. pace). Swimming times were recorded for each length (50 M.) of the race. Blood was drawn from an arm vein during the third minute of recovery for determination of lactic acid concentration. The swimming performance in the 400 M. freestyle averaged 3 sec. faster at the 7350 ft. altitude than at the 850 ft. altitude. This very slight improvement in swimming time was achieved at the expense of a much greater accumulation of blood lactate averaging 34.5% above that observed at the lower altitude. The lowered PO2 at high altitude results in a lowered maximal oxygen consumption and, consequently, an earlier build up of blood lactate in all-out work.

Nadel, E. R., Holmer, I., Bergh, U., Astrand, P. O., & Stolwijk, J. A. J. (1974). Energy exchanges of swimming man. Journal of Applied Physiology, 36, (4), 465-471.

Three male swimmers underwent 10 min. resting and 20 min swimming in a flume. Water temperatures and swim velocities varied to produce differences in maximal aerobic power. Internal body temperature changes were related to water temperature, swimming intensity and body composition. VO2 was proportional to swimming speed during submaximal efforts in any water temperature, but the increase in VO2 per increment in swimming speed became greater as the swimmer approached his maxiaml effort. Increased cost of swimming in cold water was largely attributed to shivering.

Naito, H., & Taguchi, N. (1982). Breaststroke analysis using the EMG stick picture and three dimensional model. The V International Congress on Biomechanics and Medicine in Swimming.

Armstrokes of a Japanese Olympic breaststroker and a collegiate varsity swimmer were studied using the EMG stick picture developed by Matsuda. In the computer-generated image, EMG of 6 muscles were charted. Three dimentional pulling patterns and hand pitch models were also obtained. The arm stroke of the Olympic swimmer was wider and faster than that of the varsity athlete. The pull's angle of inclination to the direction of movement was 35 degrees. The highest velocity of arm movement was observed from the time the upper arm and forearm made an angle of 120 degrees until the end of the inward scull. Discharge time for the muscles was shorter for the Olympian than for the collegian.

Neeves, R. E. (1970). The effects of hyperventilation on selected physiological variables during a static 60-second swim. Unpublished doctoral dissertation, University of Utah.

This study was to compare the effects of hyperventilation and nonhyperventilation on heart rate, respiratory rate, oxygen uptake, and carbon dioxide production. Fourteen male collegiate competitive swimmers performed a 60 sec. static swim under a hyperventilation and a nonhyperventilation condition while tethered to the side of the pool. Hyperventilation immediately prior to a static 60 sec. swim had no significant effect upon heart rate, respiratory rate, or oxygen uptake, but had a significant effect upon carbon dioxide production.

Neeves, R. E., & Brown, P. T. (1975). Sprint swimming and voluntary hyperventilation. Swimming Technique, 12, (3), 86-93.

Twelve male university swimmers were tested twice under four conditions. 1. No hyperventilation, no air collected. 2. No hyperventilation with expired air collection. 3. Hyperventilation, no air collected 4. Hyperventilation with expired air collected. Testing was done to determine if the experimental application of voluntary hyperventilation affected swimmers 100 yd. freestyle times. Slight decreases were noted, but they were not significant.

Neeves, R. E., & Singer, R. N. (1968). Effect of food consumption on 200 yard freestyle swim performance. Research Quarterly, 39, (2), 355-360.

Twelve college and high school varsity male swimmers swam 200 yd. time trials once a day for 16 days following the ingestion of a large meal (673 grams). Post-meal intervals of 1/2 hr., 1 hr., 2 hrs., or 3 hrs. were rotated for each subject. Results indicated that swimming performance time was not affected by the time interval between eating and swimming.

Ness, G. W., Cunningham, D. A., Eynon, R. B., & Shaw, D. B. (1974). cardiopulmonary function in prospective competitive swimmers and their parents. Journal of Applied Physiology, 37, (1), 27-31.

The cardiopulmonary function of 11 ten year old prospective competitive swimmers was compared with that of 9 girls who tried out for the team, but not selected, and with 13 girls who had no interest in competitive swimming. Similar comparisons were made among the childrens parents. No significant differences were observed among the group of girls or their parents in any static lung volumes, except swimmers fathers had greater FRC and TLC values.

Newman, F., Smalley, B. F., & Thomson, M. L. (1961). Comparison between body size and lung function of swimmers and normal school children. Journal of Physiology, 156, 9-10.

Lung ventilations of 30 leading British swimmers was compared with a control group of children. Measurements of vital capacity, forced expiratory volume for one sec. were higher in swimmers of both sexes. Resistance defined as pressure/flow, the ratio M.E.P./F.E.P.1 was also increased. The index M.E.P./F.E.V., a measurement of power, was higher. The differences were significant with the exception of M.E.P./F.E.V.1 in females.

Newman, J. E. (1968). The relationships among physical work capacity, physical fitness index and performance time in swimmers throughout a season of training. Unpublished master thesis, University of Alberta.

Nielsen, B. (1973). Metabolic reactions to cold during swimming at different speeds. Archieves of Science and Physiology, 27, a207-a211.

Nielson, L. M. Effect of swimming on the basic metabolism of college women. Unpublished master's thesis, University of Illinois.

This study was to determine the effect of a swimming program on the basal metabolism of 22 college swimmers of beginner to intermediate skill. Sixteen of the 22 raised their basal metabolism and the swimming program appeared to be responsible for the increase.

Nomura, T. O. (1974). The relationship of age to pulmonary function in trained swimmers at rest and during exercise. Unpublished master's thesis, University of Wisconsin. Abstract published in Medicine and Science in Sports, 6, (1), 81.

The effect of long term swim training on body stature, lung function and cardio-pulmonary function during tethered swimming and treadmill walking was

studied cross-sectionally in 29 trained swimmers (8-23 yrs.) during their competitive season. Higher than predicted normal lung volumes were associated with the trained swimmers even at the young stage, these differences could not be attributed to the length of swimming training, higher resting pulmonary diffusing capacity than normals was found. The length of training did not influence pulmonary diffusing capacity. Swimmers attained the same aerobic capacity during swimming as during upright land exercise.

Nomura, T., & Kurokawa, T. (1982). The influence of training and age on max $\dot{V}O_2$ during swimming in Japanese elite age-group and Olympic swimmers. The V International Congress on Biomechanics and Medicine in Swimming.

One-hundered-thirty-eight Japanese swimmers, aged 10 to 22, were tested for $\dot{V}O_2$ max, tidal volume, heart rate, and lactate accumulation while swimming. Swimming was performed in a flume with a progressively increasing speed. It was found that $\dot{V}O_2$ max increased to age 16 in boys, 14 in girls, and remained stable thereafter. Swimmers showed a higher $\dot{V}O_2$ max than average Japanese children of same age. The difference in $\dot{V}O_2$ max was significantly different between sprinters and distance swimmers from an early age.

Nunney, D. N. (1960). Relation of circuit training to swimming. Research Quarterly, 31, (2), 188-198.

Two groups of 12 college men were equated on the basis of distance swum in a fifteen min. endurance test using only the front crawl. Both groups were also tested for speed, height, weight, and ability to do dips, chins, push-ups, and vertical jumps. The experimental group, combined circuit training and swimming in their program, and the control group used swimming only. At the end of a 6 wk. training period, the experimental group made significant gains in endurance, speed, weight, and ability to do chins and push-ups. The control group made significant gains in endurance and weight. There was no evidence to show that the circuit training was detrimental to swimming performance.

Nygaard, E., & Nielsen, E. (1978). Skeletal muscle fiber capillarization with extreme endurance training in man. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 283-293). Baltimore: University Park Press.

This study was done to determine the optimal adaptability to endurance training in terms of fiber distribution, fiber areas, and capillary density in the skeletal muscle of man. Twenty-five swimmers, 14 boys and 11 girls, were biopsied in three muscle areas and though they showed no hypertrophy when compared with controls the observation of incisions in the cell membrane, almost dividing one cell into two, supports the concept of fiber splitting as an adaptational phenomenon in human skeletal muscle.

Oberg, D. D. (1962). Comparative analysis of a specific training and

conditioning methods pertaining to competitive swimming. Unpublished master's thesis, Eastern Illinois University.

O'Connor, N. J. (1971). The effects of two training methods in swimming classes on human pulse rates and swimming times. Unpublished doctoral dissertation, University of Northern Colorado.

This study was to determine the effects of the interval and repetition methods of training in swimming classes on pulse rate and swimming times. Eighty-one female subjects of advanced and competitive swimming ability were divided into two groups. The repetition group repeated 5 50 yd. front crawl sprints with a minute and a half rest period between each sprint. The interval group repeated 8 50 yd. front crawl sprints with a 30 sec. rest between each sprint. Pre-exercise pulse rate, 50 yd. sprint times, and post exercise pulse rates were taken. Both groups improved significantly over the 8 wk. training period. No significant differences were found between the groups. Both training methods were effective in lowering the resting and recovery pulse rate.

Ohnmacht, W. (1958). Prediction of swimming times from Cureton's 10 item fitness test for aquatic leaders. Unpublished master's thesis, University of Illinois.

Oka, Y., & others. (1963). Studies of radio telemetering on EKG and respiratory movements during running, jumping and swimming. Medical Electronics and Biomechanical Engineering, 1, 578-579.

Using transistorized telemetering on EKG and respiratory movements swimming freestyle and breaststroke showed respiratory fluctuations caused by pulse rate. The results were similar to those of long distance running.

Olbrecht, J. & Clarys, J. P. (1982). EMG of specific strength-training exercises for the front crawl. Proceedings of the V International Congress on Biomechanics and Medicine in Swimming.

Ten subjects were tested on 5 different types of dryland training apparatus while performing simulated freestyle swimming. EMG's were taken on 10 different muscles during the exercise, then compared to EMG's taken while the subjects swam the freestyle. The greatest variation from the in-water EMG patterns was noted among the equilibration muscles, followed by the propulsive muscles, then the recovery muscles.

Olbrecht, J., Madsen, O., Mader, A., Liesen, H., & Hollmann, W. (1985). Relationship between swimming velocity and lactate concentration during continuous and intermittent training exercises. International Journal of Sports Medicine, 6, 74-77.

A group of 59 national-level West German swimmers were studied to determine the relationship between velocity required during continuous 30 and 60 min. swims to produce a lactate concentration of 4mmol/l (V4). Then tested to produce the same amount of lactate during short interval repeats. Velocities for the longer swims were about the same as for a "two-speed test" done earlier. In interval training, the velocities required to produce a V4 concentration increased as the repeat distance went down. It was hypothesized that during the rest interval, a considerable regeneration of creatine phosphate occurs. As the rest interval increases, so does the proportion of CP-produced energy; thus a higher swimming speed for a given lactate level is possible.

Onoprienko, B. I. (1961). The force of swimming movement in different swimming technique. Theoretical and Practical Physical Education, U. S. S. R., 4, 842-847.

Onoprienko, B. I. (1967). Influence of hydrodynamic data on the hydrodynamics of the swimmers. Theoretical and Practical Physical Education, U. S. S. R., 10, 47-57.

Onusseit, H. F. (1968). Prediction of a swimmer's performance using speed and endurance factors. Swimming Technique, 5, 75-78.

O'Shea, J. P. (1970). The effects of anabolic steroid treatment on blood chemistry profile, oxygen uptake, static strength, and performance in competitive swimming. Unpublished doctoral dissertation, University of Utah.

The purpose of this study was to determine the effects of 3 wks. of anabolic steroid administration on blood chemistry profile, oxygen uptake, static strength, and performance in competitive swimmers. A secondary purpose was to determine the biochemical aspects, safety, and usefulness of steroid agents. Fifteen swimmers were put in one of two treatment groups. One group was administered a synthetic steroid for oral use daily while the other group was given a placebo. This procedure was reversed for the second 3 wk. period. Three wks. of anabolic steroid administration had no significant effect on oxygen uptake, static strength, or performance of competitive swimmers and had no significant biochemical effects on blood chemistry 14 profiles, with one exception being the serum enzyme levels of transaminase.

O'Shea, J. P., & Winkler, W. (1970). Biochemical and physical effects of an anabolic steroid in competitive swimmers and weightlifters. Nutrition Report International, 2, (6), 351-362.

Effects of anabolic steroid treatment on the performance of 8 competitive swimmers and 3 weightlifters was measured during an 11 wk. period. During the first 6 wks. the subjects were administered 10 mg/day of oxandrolone, a synthetic steroid for oral use. Significant alterations were noted in the lactate dehydrogenase, creatine phosphokinase, urea nitrogen, iron, the LDH isoenzyme fractions of LD 1 and LD 5, and protein metabolism. No toxic side effects as edema, impaired hepatic function, or changes in electrolyte balance were noted. Strength was significantly increased in weight lifters. There was no evidence that steroid treatment had any effect on improving performance (speed) in competitive swimmers.

Parchman, L. (1961). Comparative study of the development of leg strength and endurance of college women in basketball and swimming. Unpublished master's thesis, University of Illinois.

The purpose of this study was to determine and compare the development of strength and endurance of 31 college women after a semester of swimming and basketball. They were tested for strength on a back and leg dynamometer and for endurance on a bicycle ergometer. There was a significant improvement in leg strength in the basketball group. Neither group increased significantly in endurance.

Patton, R. W., Young, W., Richardson, P., Watson, J., & Raven, P. B. (1979). The effects of hypoxic training upon sprint freestyle swimming performance. Swimming Technique, 16, (3), 89-92.

The effect of hypoxic training on performance of the 50 and 100 yd. freestyle swimming events was determined on 38 male and female high school varsity swimmers prior to and following a 10 wk. training period. Hypoxic techniques were effective at the 100 yd. distance but not at 50 yds.

Payne, W. R., & Lemon, P. W. R. (1982). Comparison of anaerobic threshold during treadmill running and tethered swimming in competitive swimmers. Medicine and Science in Sports and Exercise, Abstracts, 134, (2), 128.

Anaerobic threshold values were compared for 6 male competitive swimmers during treadmill running and tethered swimming. Data indicate that although running and swimming display many descriptive physiological differences, specific arm training results in an anaerobic threshold during tethered swimming that is not different from treadmill running.

Pendergast, D. R. (1973). An analysis of the oxygen cost, mechanical work, and efficiency of swimming the overarm crawl at two velocities. Unpublished doctoral dissertation, State University of New York at Buffalo.

This investigation was to describe and validate a method of evaluating swimming performance utilizing precise measurements of net oxygen consumption,

body drag, efficiency, and proficiency of a free swimming subject. Ten male subjects from 15 to 26 yrs. of age who were highly trained swimmers performed the overarm crawl at a high and low velocity and swam under six different experimental conditions while expired gas was collected, and heart rate was measured during the steady state period. The experimental conditions were velocity and drag. The method of determining net oxygen consumption, body drag, and efficiency of free swimming was concluded to be valid and reliable. Values determined for oxygen consumption of free swimming were comparable to those found by others. The body drag and efficiencies were not. the oxygen cost, body drag, and efficiency of swimming the overarm crawl at a high velocity are greater than for a low velocity. Ratio of the efficiency of free swimming and the body drag of free swimming was a valid method of determining swimming proficiency.

Pendergast, D. R., Diprampero, P. E., Craig, A. B., Jr., & Rennie, D. W. (1978). The influence of selected biomechanical factors on the energy cost of swimming. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 367-378). Baltimore: University Park Press.

This is not an experimental study, but presents a format for analyzing swimming performance by examining the basic equations that govern the overall energetics of performance as they apply to swimming. The ratio of net mechanical efficiency over drag is discussed.

Pendergast, D. R., Wilson, D. W., Diprampero, P. E., & Rennie, D. W. (1974). Energy cost of swimming. Medicine and Science in Sports, Abstract, 6, (1), 86.

The purpose of this study was to apply a method of analysis of free swimming to 25 skilled men and 12 women utilizing the overarm crawl at varving velocities. The theoretical velocity maximum of women is estimated to be about 95% of that of men, which closely approximated that observed in the distance events of the 20th Olympic games (94%). It was concluded that the women expend less energy per unit distance than men, even when corrections are made for smaller body size, with their maximum velocity being limited by the VO2 max.

Phillips, H. (1941). Physiological effects on college women of immersion in water 65-75 degrees F.- temperature change. Unpublished master's thesis, Wellesley College.

To determine the physiological effects on 18 college females of immersion in water of 65 to 75 degrees F. subjects were immersed in water of 75, 70 and 65 degrees F. for a period of 15 min. A fourth immersion, for which a subject was covered with vaseline, was made at 65 degrees F. A thermocouple and galvanometer were used for taking oral and axillary temperatures, and skin temperatures on the chest, thigh, finger, and toes. Temperatue readings were taken prior to the immersion and at 5 min. intervals during immersion. there was a decrease in oral and axillary temperature and in skin temperature on the chest, thigh, fingers, and toes for all water temperatures. With the exception of oral temperature, the amount of decrease varied with the coldness

of the water. The rate of the decrease in axillary and skin temperatures was rapid, the greatest change coming within the first 5 min. of immersion. the extremities reach a lower temp. than other parts of the body in which there is a greater blood supply. At each water temp. it was found that at the end of 15 min. oral temp was highest, axillary temp. was slightly lower, chest and thigh temp. were intermediate, finger and toe temp. were lowest being about the same temp. as the water in which immersed. The effect of greasing was to raise the temp. of the body prior to immersion.

Pickens, W. L. (1950). Study of flexibility in swimmers. Unpublished master's thesis, University of Oregon.

This study was to determine if swimmers exhibit a greater or lesser degree of flexibility in specific joints than do athletes in other sports and to determine if swimmers are more flexible or less flexible than college males not specialized in a particular sport. There was no one measure in which swimmers were significantly more flexible than other groups. A point system for ranking groups in flexibility found that swimmers ranked highest in flexibility however.

Piette, G., & Clarys, J. P. (1979). Telemetric EMG of the front crawl movement. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 153-159). Baltimore: University Park Press.

Twelve male subjects, 6 swimmers and 6 non-swimmers, had EMG measurements compared and differences in intensity of contraction was noted. Great inter-individual variation occured among the competitive swimmers.

Pipes, T. V. (1978). Isokinetic strength training and its effectiveness for the competitive swimmer. Swimming Technique, 15, (2), 52-53.

The purpose of this study was to test a high-speed isokinetic strength training program and its effectiveness in improving the performance of competitive swimmers. A total of 20 competitive female swimmers between the ages of 13 and 17 yrs. participated in an 8 wk. study. High speed isokinetic strength training was found an effective means of increasing muscular strength without significant changes in body weight or muscle size. The training produced significant increases in lean body weight with concomitant decreases in relative body fat. Significant improvement in performance was found in the competitive swimmers times.

Pipes, T. V. (1978). Varied strength training programs utilizing isokinetic resistance. Swimming Technique, 15, (3), 83-86.

The purpose of this study was to investigate what number of repetitions and length of time is most beneficial in isokinetic training for strength gains and improved athletic performance.

Sixty competitive swimmers ranging in age from 14-18 yrs. were in this 8 wk. study. Divided into 5 groups, 4 pursuing strength training on isokinetic resistance equipment and 1 serving as a control group. The training was found to significantly increase the strength and improve the performance of competitive swimmers.

Pleasants, F., Jr. (1969). Pre-training and post-training swimming endurance of smokers and nonsmokers. Research Quarterly, 40, (4), 779-782.

This study was to investigate the swimming endurance trainability of smokers as compared to nonsmokers. The 47 nonsmokers and 34 smokers of college age were selected from intermediate swimming classes and timed while swimming distances of 100 and 200 yds. prior to participation in an 8 wk. training program. After 4 wks. of training, times were again recorded for the same distances. At the end of 8 wks., times were taken for these distances and for 400 yds. The mean changes of both smokers and nonsmokers during the pretraining to 4-wk. period, the 4-wk. to 8 wk. period, and the pretraining to 8 wk. period were all significant. However, no significant differences were found between the mean swimming times of smokers and non smokers for any of the pretraining, 4-wk., or 8-wk. distances.

Pleasants, F., Jr., Grugan, J., & Ratliff, J. W., Jr. (1967). Effects of short periods of abstinence from cigarette smoking on swimming endurance of chronic smokers. Research Quarterly, 38, (3), 474-479.

This study investigates the effects of 15 min. 2 hrs., and 12 hrs. abstention from cigarette smoking on the swimming endurance of male college students who had been smoking regularly for at least 1 year. The subjects were divided into 3 groups which rotated through the 3 periods of abstinence for 6 successive testing days. During the first 3 testing days each period of abstinence was followed by a 100 yd. swim which was timed and recorded to the nearest second. This same procedure was followed for the additional 3 testing days using a distance of 200 yds. None of the differences was significant.

Poe, G. H., III (1969). The relationship of selected anathropometric measurements to swimming time of college varsity swimmers in the fifty-yard front crawl stroke, Unpublished master's thesis, Springfield College.

Anthropometric measurements were examined and compared to swimming speed for 50 yds. of front crawl. Only hand width was statistically significant when compared to swimming speed.

Pomfret, J. B. (1962). Experiment to determine the relative effectiveness of improved swim time when using the freestyle throw-away turn. Unpublished master's thesis, University of Washington.

Poulos, G. E. (1949). An analysis of the propulsion factors in the American crawl stroke. Unpublished master's thesis, State University of Iowa.

Prior, T. B. (1969). Tethered swimming under acute exposure to four simulated altitudes. Unpublished doctoral dissertation, Indiana University.

This study was to determine the differences in physiological effects produced by 4 simulated altitudes on highly trained subjects swimming to exhaustion in a tethered situation. Variables were, swim time to exhaustion, maximal oxygen consumption, maximal heart rate, maximal ventilation, maximal respiration rate, tidal volume, maximal carbon dioxide expired, blood lactate concentration, and respiratory exchange ratio. Sixteen varsity swimmers were tested with a Balke style swimming test while they breathed simulated altitude gas mixtures. Swim time to exhaustion, maximal oxygen consumption, and maximal carbon dioxide expired by subjects showed a significant linear decrase with progressively higher simulated altitudes. Heart rates demonstrated a significant linear decrease at the simulated altitudes higher than Denver. Mean respiratory exchange ratio showed a significant linear increase with higher simulated altitudes, but not at those of Denver and Mexico City. During exhausting exercise at increasingly higher altitudes, tethered swimmers are handicapped in the same manner as treadmill runners and bicycle ergometer riders. The retarding effects of simulated high altitude upon tethered swimming performance times begin at as low an altitude as 4920 ft.

Raney, D. P. (1932). A study of swimming efficiency. Unpublished master's thesis, State University of Iowa.

The purpose of this study was to devise a method for measuring swimming efficiency of junior high school boys and to compare them with college men. The pulse-ratio test was used to determine the efficiency of 98 junior high boys and 5 college men. College trained swimmers were slightly more efficient in executing the side stroke than trained junior high boys.

Rebillard, R. (1970). The relationship of aquatic performance and a swimmer's ability to interpret aquatic stimuli through extroception of the hand. Unpublished master's thesis, Southern Connecticutt State College.

An intrument was developed to test aquatic stimulation on the hands of 19 varsity swimmers. A significant relationship was found between swimmer's ability to interpret aquatic stimuli with the hand and their swimming ability.

Reddan, W. G. (1966). Pulmonary characteristics of trained university oarsmen, swimmers and cross-country trackmen. Unpublished doctoral dissertation, University of Wisconsin.

This study was to determine if trained varsity oarsmen, swimmers and cross-country trackmen differ with respect to selected tests of pulmonary function taken at rest and under standard exercise conditions. Eight varsity

crew members, 11 varsity swimmers and 9 varsity cross-country runners were measured at rest to determine static lung volumes, several anthropometric measures were taken. Continuouse recordings of inspired and mixed expired CO2, CO, O2, ventilation and heart rate were made during steady state exercise on a bicycle ergometer at varying work loads. There were no differences among trained varsity crewmen, swimmers and cross-country men in static lung volumes, and ventilatory capacity at rest or in pulmonary diffusing capacity at rest or in exercise, or in components of diffusing capacity, pulmonary capillary blood volume and diffusing capacity of the alveolar membrane at rest or at exercise. Athletes did not differ from untrained college men in static lung volumes or ventilatory capacity when body size was held constant, or pulmonary diffusing capacity at rest or during exercise.

Reddan, W., Burpee, J., Reuschlein, P., Gee, J. B., & Rankin, J. (1966). Pulmonary adaptation to strenuous training in competitive swimmers. Federation Proceedings Abstracts, 25, 325.

This study was to determine the effects of a 6 mo. aquatic training season on alveolar capillary gas exchange during rest and steady state submaximal exercise on 11 varsity swimmers. Compared with other athletic groups and controls, the cronic effects of training in swimmers differed in a significant decrease in pulmonary capillary blood volume during strenuous work and in supine and upright position at rest which was associated with a significant decrease in pulmonary diffusing capacity which appeared to be the result of training. Reduction in body blood volume was found and an increased oxygen extraction and aerobic capacity was evident.

Reeves, J. A. (1962). Study of various types of balance and their relationship to swimming endurance and speed. Unpublished master's thesis, Pennsylvania State University.

This study was to determine if the acquisition of swimming skill improves ability in various types of balance and to determine the relationship between these abilities measured after swimming instruction and level of swimming endurance or speed attained. Eighty-three university students rated as non-swimmers were given preliminary balance tests on seven tests of balance. After 6 wks. of swimming instruction, speed and endurance of swimming was tested and they were retested on the balance tests. No relationship was found between improvement in balance and swimming speed or endurance.

Rennie, D. W., Pendergast, D. R., di Prampero, P. E., Wilson, D., Lamphier, E. H., & Meyers, C. R. (1973). Energetics of the overarm crawl. Medicine and Science in Sports, Abstracts, 5, (1), 65.

The purpose of this study was to determine how body drag and mechanical efficiency of the swimmer govern the relationship between swimming velocity and total net energy expenditure in the overarm crawl. The average VO2 of 20 male swimmers increased, as did drag and mechanical efficiency.

Rennie, D. W., Pendergast, D. R., & di Prampero, P. E. (1975). Energetics of swimming in man. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp. 97-109). Baltimore: University Park Press. Reprinted in (1977). Swimming Technique, 13, (4), 112-114.

The VO2 max. of women swimmers is related to their body drag. Their smaller body drag is due primarily to a smaller surface area and their higher overall mechanical efficiency is related to their greater buoyancy.

Reynolds, W. E. (1964). Training and conditioning swimmers by a general and an experimental sprint method to determine the effect of each on speed of swimming fifty yards. Unpublished master's thesis, University of Maryland.

The purpose of this study was to determine whether the selected training program would increase speed of swimming 50 yds. in the course of an 8 wk. training period and to determine which of two programs would produce greater gains in speed. Twenty-eight college males in advanced swimming classes were equated into two groups, a general and a sprint group. Both groups were given an 8 wk. training program and were tested before and after the training program. Both methods produced significant improvement in swimming speed. No significant difference was found between the groups.

Rhodes, E. C., McKenzie, D. C., & Potts, J. (1983). Determination of anaerobic threshold in elite female swimmers. Medicine and Science in Sports and Exercise, Abstracts, 15, (2), 108.

The purpose of this study was to investigate the use of excess CO2 as a determinant of the anaerobic threshold and the relationship of other metabolic parameters in 10 highly trained elite female swimmers. Metabolic and respiratory exchange variables were assessed by an open circuit method. Findings are similar to metabolic parameters reported for treadmill running.

Riedel, E. (1965). A survey of practices of swimming coaches concerning weight training programs. Unpublished master's thesis, California State University, Sacramento.

This study was to survey the practices of swimming coaches in the states in relation to the use of systematic weight training programs and their effect on competitive swim performance. Questionnaires were returned by 106 swimming coaches. Of this group 35 had no weight training program and 71 had programs. The majority used weight training programs because of their significant positive effect on swimming performance.

Rilea, R. E. (1960). Application of the overload principle on the improvement of swimming performance. Unpublished master's thesis, Florida State University.

The purpose of this study was to determine if there was any difference in performance of the back crawl while working in fatigue as compared to working in non-fatiguing conditions. Subjects were 25 women undergraduates from regular swimming classes on the university level. No significant differences were found between the two groups in either form or speed in the back crawl.

Robertson, D. F. (1960). Relationship of strength of selected muscle groups and ankle flexibility to the flutter kick in swimming. Unpublished master's thesis, State University of Iowa.

This study was to determine the relationship of the strength of selected muscle groups and the relationship of ankle flexibility to the velocity and propulsive force of the flutter kick. Seventeen varsity or accomplished swimmers were tested in hip-flexion, hip extension, and knee extension strength, ankle flexibility, velocity in the flutter kick, and propulsive force generated by the flutter kick. Statistically significant correlations were obtained between velocity and propulsive force. It is concluded that ankle flexibility is an important factor in the propulsive force generated by the flutter kick and that exercises to increase ankle flexibility are worthwhile.

Robinson, P. S. K. (1974). The physiological effects of chronic heavy physical training on female age-group swimmers. Unpublished doctoral dissertation, Ohio State University.

The purpose of this study was to determine the effects of chronic heavy physical training upon selected physiological, physical, and anthropometric variables in 12 female age group swimmers. Twelve non-swimming females were used as a control group. Subjects participated in an interval training program as much as 12000-14000 M. per day, 6 days per wk. The control subjects engaged in regular activities, but not allowed to train in age group swimming or track. Tests given to all subjects were a maximal bicycle ergometer test, muscular strength measurements, and selected anthropometric and skinfold dimensions. A sample of the experimental group were also tested for resting systolic pressure and for cardiac output during submaximal exercise performed on a bicycle ergometer. The maximal oxygen consumption increased significantly for the experimental group. The maximal pulmonary ventilation showed a significant increase in the control group. Maximal respiratory exchange ratio increased significantly in the control group. The resting heart rate significantly decreased in the controls. The experimental group showed a significant increase in the lean body weight with training. Percent body fat increased for the controls. The body density decreased significantly in the control group.

Robinson, P. S., Caffrey, G. P., Ridinger, R. R., Steinmetz, C. W., Bartels, R. L., & Shaffer, T. E. (1978). Metabolic effects of heavy physical training of female age group swimmers. British Journal of Sports Medicine, 12, 14-21.

Twelve female age-group swimmers and 12 female controls, aged 10-16, performed a pre-training discontinuous maximal cycle ergometer test to determine the capacities of their anaerobic (alactacid and lactacid) and aerobic energy systems. Heart rate and oxygen uptake were determined during rest, exercise, and recovery. Blood samples were collected before and after exercise for determination of blood lactic acid concentrations. Tests were regiven to both groups immediately following the swimmers' competitive season. It was concluded that female swimmers possess significantly superior oxygen transport systems as compared to the untrained controls and that the high level of aerobic fitness is maintained throughout their training.

Rodahl, A., O'Brien, M., & Firth, R. G. R. (1976). Diurnal variations in performance of competitive swimming. Swimming Technique, 13, (3), 93-95.

Twenty-two subjects, 10 boys and 12 girls, from 11 to 23 yrs. took part in this study on diurnal variations. Swimmers maxiaml aerobic power was predicted, using a bicycle ergometer and measuring heart rates at submaximal loads. Of 85 observations, 61 had faster times in the evening, 23 were not as good in the evening and one was the same. Evidence is shown that their is a diurnal variation in swimming performance. Times being generally better in the evening.

Rohter, F. D. (1962). Effects on swimming speed of starting from a dry body state. Research Quarterly, 33, (1), 140-142.

Ten competitive swimmers were timed for a 50 M. race after immersing themselves in the pool for two min. before the trial and without immersing themselves prior to the time trial. The dry state times were significantly faster than the wet state times.

Ross, D. T. (1970). Selected training procedures for the development of arm extensor strength and swimming speed of the sprint crawl stroke. Unpublished doctoral dissertation, University of Arkansas.

This study was to determine the effectiveness of four different training procudures used in the development of arm extensor strength and swimming speed of the sprint crawl stroke. Procedures were, swimming only, weight training, swimming against progressively increasing resistance, and dryland exer-genie exercises. Another purpose was to determine the relationship between an increase in arm extensor strength and an increase in swimming speed. Seventy-two unskilled swimmers trained for 45 min. 3 days a wk. for 6 wks. They were effective in improving arm strength and speed of swimming. Weight training, resistance swim, and the exercise training procedures were significantly more effective in increasing arm strength and swim speed than swimming only. The weight training and exercise methods were significantly more effective in developing arm strength than was resistance swimming method. Weight training group had significant weight gain. A significant negative correlation between an increase in arm strength and an increase in

swimming speed of subjects in swimming group only was found. No significant correlation between an increase in arm strength and swimming speed was found in other groups.

Roth, G. M., & Gabrielson, M. (1940). Variation of the concentration of the acidity of the gastric contents in normal subjects before and following immersion of hand and entire body in water at various temperatures. American Journal of Physiology, 129, 451.

The effect of body immersion in water at temperatures of 65-108 degrees F. on the gastric acidity of 5 normal subjects was studied. Two swam 5-6 times a wk., other 3 swam 3-4 times during the 4 mo. period. Immersion in cold water between 65-85 degrees F. caused a definite rise in the gastric acidity 15 min. after removal from water. Temperatures close to and above body temp. had little effect on the gastric acidity.

Rowe, E., Maglischo, E. W., & Lytle, D. E. (1977). The use of swim fins for the development of sprint swimming speed. Swimming Technique, 14, (3), 73-76.

Thirty-two 7 and 8 yr. old age group swimmers were separated into an experimental group that trained with swim fins and a control group that trained in a conventional manner. Both groups improved their 25 yd. sprint time over the 6 wk. training program, but the sprint-assisted method using the swim fins was significantly superior to the conventional training program for improving 25 yd. freestyle speed.

Ryan, A. J. (1977). Studies on swimmers predict performance. Physical Sports Medicine, 5, 18.

Ryan, D., & Ecker, R. E. (1976). A new approach to nutritional programming for competitive swimmers. Swimming Technique, 13, (3), 72-79.

This study describes changes in body weight, strength and swimming performance for 10 male college swimmers subjected to a season long nutritional programming. Data is given in table form.

Saito, M. (1979). An analysis of swim performance after swimming lessons for three years in untrained high school students. (in Japanese). Taiku No Kagaku, 29, 484-488.

Saito, M. (1982). The effects of training on the relationships among velocity stroke rate and distance per stroke in untrained subjects swimming the breaststroke. Research Quarterly for Exercise and Sport, 53, (4), 323-329.

This study was to determine the relationships among velocity stroke rate, and distance per stroke in the breaststroke. Total of 168 high school students were tested. A videotape record with timer was used to measure swimming time and strokes during maximum effort for 50 M. It was found that velocity is significantly related to distance per stroke before and after training, but has no relationship to stroke rate.

Salo, D. C. (1982). Short, sweet and powerful: training with short repeats above race speed. Swimming Technique, 4, 19-23.

Seven male swimmers were trained in accordance with a described protocol of high velocity overload training. They ranged in age from 12 to 23 and in ability from Junior Olympic qualifiers to NCAA finalists. The training was effective in producing significant improvements in swimming performance.

Salo, D. C. (1984). High-intensity training and freestyle performance. Swimming Technique, 21, (1), 20-23.

The purpose of this study was to determine the effects of high-velocity training on performance capacity of a single subject at distances of 25, 100, and 500 yds. He was able to improve performance at 100 and 500 yds., but not at 25 yds. during 10 wks. of high-intensity sprint swim training.

Sawka, M. N., Knowlton, R. G., Miles, D. S., et al. (1979). Post competition blood lactate concentrations in collegiate swimmers. European Journal of Applied Physiology, 41, 93-99.

Blood lactate concentrations taken 5 min. after individual competitions in an intercollegiate swim meet were higher than those recorded by the same 20 subjects after maximal effort 100 and 200 yd. freestyle workout swims 2 wks. earlier. Subjects competing in the 200 IM showed the highest lactate measurements (25.7 mosm/liter), perhaps because of use of a greater number of fast twitch fibers. Conversely, those competing in the 500 and 1000 yd. freestyles showed significantly lower lactate levels.

Scherwat, D. H. (1951). Effects of ultra-violet radiation on the cardiovascular fitness of varsity swimmers. Unpublished master's thesis, University of Illinois.

This study was to determine whether metabolism and cardiovascular fitness of a group of 12 varsity swimmers in training would be effected by a regularly scheduled exposure to ultraviolet radiation. Ultraviolet light given in systematic exposure did improve the cardiovascular systems of a trained swimmer. Greater speed for the heart rate to return to normal after exercise after exposure to ultraviolet radiation was found. The stroke and minute volume

of the heart were increased by systematic exposure to radiation. Swimmers reported less colds. Ultraviolet radiation did not have a lasting effect upon the swimmers cardiovascular system. Irridiated subjects raised their BMR 14% over the non-irridiated control subjects.

Schleicher, R. (1965). The validity of cord-stretching strength exercises in competitive swimming. Unpublished master's thesis, University of Illinois.

Schovone, R. M. (1975). The effects of pull-kick training. Swimming Technique, 12, (1), 18.

This study was to evaluate the effects of 3 training methods on competitive swimming performance. They were the whole stroke method, the pull-kick method, and a combined method. Significant improvement resulted from all 3 methods, but no differences between the methods.

Scogin, H. D. (1969). A comparison of swimming performances following selected intensities of warm-up with varied rest intervals. Unpublished doctoral dissertation, University of Arkansas.

This study was to compare the swimming performances of university varsity swimmers following selected intensities of swimming warm up when the length of the rest interval between warm up and performance was varied. The mean times for swimming 100 yds. using the crawl stroke was compared following 7 conditions of warm up. 1. No warm up. 2. Moderate warm up with a 2 min. rest interval. 3. Moderate warm up with a 15 min. rest interval. 4. Moderate warm up with a 30 min. rest interval. 5. Heavy warm up with a 2 min. rest interval. 6. Heavy warm up with a 15 min. interval. 7. Heavy warm up with a 30 min. interval. Ten varsity swimmers had 6 mo. of intensive conditioning. For the group as a whole, swimming performance was not significantly different under any of the warm up conditions.

Scott, J. D. (1967). The effect of isometric and elastic cord exercises on strength and speed of swimming. Unpublished doctoral dissertation, University of Missouri.

This study was to ascertain the effects of functional isometric and elastic cord exercises on speed of swimming, to ascertain the frequency of elastic cord exercises necessary to maintain a strength level attained by these exercises, and to compare the effects of isometric and elastic cord exercises on strength. Three groups of 17 college males were subjects. Functional isometric exercises brought about significant gains in arm strength. Both functional isometric exercises and elastic cord exercises brought about significant gains in arm strength. The additions of both programs to a swim program will produce positive speed results beyond that of a swimming program alone. Exercises performed once every 2 wks. retain a strength level as well as elastic cord exercises performed once per wk.

Secher, N. H., & Oddershade, I. (1975). Maximal oxygen uptake rate during swimming and bicycling. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp. 137-142). Baltimore: University Park Press.

This study was to determine the influence of arm fitness on maximal oxygen uptake during swimming. Ten young males with marked differences in swimming experience swam selected arm and leg strokes while swimming in a flume. Trained swimmers had oxygen consumptions during swimming of more than 89% of their running or cycling values. Recreational swimmers had values less than 88% of their running or cycling values.

Selby, G. B., & Eichner, E. R. (1985). Intravascular hemolysis and iron depletion in distance swimmers. Medicine and Science in Sports and Exercise, 17, (2), 293.

Seven conditioned swimmers were studied immediately before and after a 1.5-km race and 9 studied after a 10-km race. It was concluded that normal distance swimmers have mild, effort-related, intravascular hemolysis during a long race. Also, swimmers like runners, can have markedly low ferritins while maintaining normal hemograms.

Sharman, I. M., Down, M. G., & Sen, R. N. (1971). The effects of vitamin E and training on physiological function and athletic performance in adolescent swimmers. British Journal of Nutrition, 26, 265-276.

Two experimental groups, each of 13 male swimmers, were given either vitamin E or a placebo daily in addition to their normal diet during training in swimming and various athletic activities over a 6 wk. period. Evaluation of the experimental treatments was made from tests of anthropometric status, cardio-respiratory efficiency and motor fitness and performance, which were administered at the beginning and end of the experimental period. Whereas training significantly improved physiological function and performance in both groups, vitamin E did not.

Sharp, R. L., Troup, J. P., & Costill, D. L. (1982). Relationship between power and sprint freestyle swimming. Medicine and Science in Sports and Exercise, 14, (1), 53-56.

To determine the role of power in sprint swimming, 40 competitive swimmers (22 females and 18 males) were tested for arm power at different velocities using the biokinetic swim bench. A close relationship was found between power output and sprint swimming performance (r=0.90). Power as measured in this study offers an objective assessment of a component essential for success in sprint swimming.

Sharp, R. L., Troup, J. P., Richardson, A. B., & Stanford, P. D. (1984). Blood lactate profiles of 1984 U. S. Olympic swimmers: comparison with sub-elite collegiate competitors. Medicine and Science in Sports and Exercise, Abstracts, 16, (2), 193.

Blood lactate profiles were developed for track and swimming competitors by determining blood lactate after a sub maximal sport specific exercise bout and a maximal sport specific bout. These profiles were given to 73 Olympic swimmers preparing for the 1984 games. These blood lactate profiles seemed capable of sensing differences in performance ability and can be used as a sport specific field test for monitoring the progress of the training program.

Sharp, R. L., Vitelli, C. A., & Costill, D. L. (1981). Comparison of lactic acid-velocity and heart rate-velocity profiles in competitive swimmers. International Journal of Sports Medicine, 2, 274.

A lactic acid vs. velocity profile as a training monitor has been proposed for competitive swimmers and since heart rate and exercise intensity are closely related this study proposes that a heart rate-velocity model could provide the same information. The changes due to swim training in these models were examined in 12 male swimmers. Profiles were made using 200 yd. freestyle swims on each swimmer pretraining and following 2 mo. swim training. There was a significant correlation between pretraining and lactic acid vs. velocity. It was concluded that both profiles are capable of sensing changes in training status of swimmers. Thus the heart rate-velocity profile offers a viable alternative to the expense of blood lactate measurement.

Sharp, R. L., Vitelli, C. A., Costill, D. L., & Thomas, R. (1984). Comparison between blood lactate and heart rate profiles during a season of competitive swim training. Journal of Swimming Research, 1, (1), 17-20.

This study was to determine if blood lactate/velocity and heart rate/velocity profiles would sense the changes in endurance capacity associated with a season of competitive swimming training. It was hypothesized that a heart rate/velocity profile could provide the same information concerning the success of training programs as the lactate/velocity profiles proposed by Mader in 1976. Twelve male college swimmers performed two 200 yd. swims at 3 times during the season. Once at the beginning, after 2 mo. of training, and after 4 mo. of training. Blood samples and heart rates were taken after each swim. Results indicated that both profiles showed a significant right-ward shift during the first 2 mo. and a small further shift during the final 2 mo. The correlation between actual and predicted performance was low. Both monitoring techniques are sensitive to adaptations made to training and can provide information to the coach and athlete concerning the relative effectiveness of the program. The heart rate profile was found a useful and non-invasive alternative to blood lactate testing.

Shephard, R. J. (1967). Physical performance of unacclimatized men in Mexico City. Research Quarterly, 38, (2), 291-299.

The physical performance of a swimmer and two accompanying laboratory staff members (normally resident at an altitude of 550 ft.) were studied during a six day visit to altitude, (7,374 ft.). Swimming times were below standard; a decrease of maximum work capacity observed; a higher pulse rate during submaximal work, and slower recovery of pulse rate after exercise were found. Vital capacity was unchanged, but forced expiratory volume, maximal midexpiratory flow, and peak expiratory flow rate all showed some increase. The arterial PCO2 was lower, and the arterial ph was increased, but the standard bicarbonate showed no consistent change. A small increase in red cell count occurred.

Shepperd, R. J., Godin, G., & Campbell, C. (1974). Characteristics of sprint, medium, and long distance swimmers. European Journal of Applied Physiology, 32, 99-116.

Siebers, L. S., & McMurray, R. G. (1981). Effects of swimming and walking on exercise recovery and subsequent swim performance. Research Quarterly for Exercise and Sport, 52, (1), 68-75.

Six female college swimmers were used to test the hypothesis that the recovery procedure after exercise will not only affect subsequent performance but will also affect the recovery process after the subsequent performance. Each swimmer exercised for two min. at 90% VO2 max. on a swimming ergometer, recovered for 15 min. by walking on land or swimming, then swam 200 yds. for time. The swimming recovery reduced the lactate levels by 53.3% compared to a 38.5% reduction during the walking recovery. It was concluded that a 15 min. recovery period may be sufficient for repeated bouts of high intensity work lasting less than three min. It was also concluded that self-selection of the mode of recovery is not always the most effective for removal of blood lactate.

Simmons, R. W. F., & Hardt, A. B. (1973). The effect of alkali ingestion on the performance of trained swimmers. Journal of Sports Medicine, 13, (3), 159-163.

Improvement in times of sprinters and distance swimmers was measured during a 5 wk. period. The rate of alkali excretion in the 8 trained swimmers was also compared with the rate in 8 untrained swimmers during a five hr. period following alkali ingestion. The performance of 100 yd. sprint swimmers who received alkali was found to be significantly improved over the performance of sprint swimmers receiving a placebo. Alkali ingestion can improve the performance of trained sprint swimmers to a limited degree. An

important increase in buffer capacity appears to be acquired natually through intensive training, and this increase may be the result of decreased alkali excretion.

Sjogaard, G., & Nielsen, B. (1983). Water and electrolyte shifts during prolonged swimming and bicycling. Medicine and Science in Sports and Exerecise, Abstracts, 15, (2), 97.

To determine differences in water loss from the plasma and uptake by the exercising muscles, five healthy men, 20-30 yrs. performed 90 min. of cycling with their legs horizontal, or of swimming with the legs only. Plasma volume was decreased in both exercises at 20 min., but only with cycling a further decrease occured at 90 min. A similar pattern was seen for the increase in plasma. Muscle biopsies from vastus lateralis demonstrated an increase in water content within 20 min. in both exercises, A further increase occured in cycling. The muscle plasma content was significantly decreased only at the end of bicycling.

Sloan, R. E. G., & Keatinge, W. R. (1973). Cooling rates of young people swimming in cold water. Journal of Applied Physiology, 35, 371-375.

Body temperature of the younger and thinner members of a group of boys and girls aged 8-20 yrs. fell by up to 3.2 degrees C. when they swam for up to 40 min. in water at 20.3 C., at an energy expenditure of about 4.8 kcal/min. The rate of cooling correlated well regardless of age or sex with the individual's overall surface fat thickness on both trunk and limbs; the correlation was improved by making allowance for differences in surface area/mass ratio. Fat thickness was less and fall in body temperature more rapid in young than older swimmers, and in boys than girls, even after correction for surface area/mass ratio. Regional differences in fat distribution were less important, but older swimmers and boys, of given trunk fat thickness generally had less limb fat and cooled faster than younger swimmers and girls, of similar trunk fat thickness and surface area/mass ratio.

Sloan, R. H. (1966). An analysis of 1965 off-season training regimens of big ten swimmers. Unpublished master's thesis, University of Illinois.

This study was an investigation of the off-season training regimens of big ten swimming teams to evaluate causal relationships to conference standings in 1966. Data from 105 varsity swimmers found that teams ranking in the upper division had the greater amount of off-season training.

Smit, P. J., Daehne, H. O., Van Wyk, G., & Steyn, E. S. (1979). Interval training and the progressive load principle in novice child swimmers. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp.240-249). Baltimore: University Park Press.

The aim of this study was to determine which method, long distance training or interval training, was more suitable for the advancing the swimming of prepubertal children. Improvement in swimming times and physiological and biomechanical variables were measured before and after a winter training program. findings strongly suggest that interval training is superior as an intermediary program.

Smith, B. W., McMurray, R. G., & Symanski, J. D. (1982). Anaerobic threshold of trained swimmers. Medicine and Science in Sports and Exercise, Abstracts, 14, (2), 161.

Anaerobic threshold was evaluated in 12 competitive swimmers; six whose primary event was 200 yds. or less and six whose event was 400 yds. or more. The threshold for sprinters averaged significantly lower than for the endurance swimmers.

Smith, B. W., McMurray, R. G., & Symanski, J. D. (1984). A comparison of the anaerobic threshold of sprint and endurance trained swimmers. Journal of Sports Medicine, 24, 94-99.

Refer to Smith, B. W., McMurray, R. G., & Symanski, J. D., (1982).

Smith, D. C. (1959). Correlation of arm extension strength training with speed swimming. Unpublished master's thesis, University of California.

Smith, G. M., & Beecher, H. K. (1959). Amphetamine sulfate and athletic performance. Journal of American Medical Association, 170, (5), 542-557.

The purpose of this study was to determine whether or not amphetamine sulfate (pep pills) improves performance in trained athletes. In two experiments swimmers were used. The medicaments were given orally, and performnces were measured from 2-3 hrs. after subjects had been given either amphetamine or placebo. The majority of subjects performed better under influence of amphetamine. The improvement was statistically significant.

Smith, G. M., Weitzner, M., & Beecher, H. K. (1963). Increased sensitivity of measurement of drug effects in expert swimmers. Journal of Pharmacology, 139, 114-119.

The effect of amphetamine, and secobarbital, on the performance of 15 non-expert swimmers were compared with the effects of these drugs on the performance of 15 expert swimmers. Each subject swam 24 times: 8 times after taking amphetamine, 8 times after taking secobarbial, and 8 times after taking a placebo. Amphetamine improved the performance of expert and non-experts to similar degrees. Secobarbital impaired the performance of both

groups - possibly more so with experts than with non-experts, but this was not conclusive.

Smith, R. G. (1962). Study of the relationship between leg strength and swimming speed using the flutter kick in the prone position. Unpublished master's thesis, Montana State University.

This study was to determine the degree of relationship between the strength of selected lower extremity movements and the time needed to complete a 20 yd. kicking test. Forty-three subjects , college age males, swam a 20 yd. distance in the prone position holding a kick board. The muscle groups tested were hip flexors, knee extensors, hip extensors, knee flexors and ankle plantar flexors. A negligible relationship between the best times achieved on the kicking test and total ankle plantar flexor strength was found.

Sobolova, V., Seliger, V., Grussova, D., Machovcova, J., & Zelenka, V. (1971). The influence of age and sports training in swimming on physical fitness. Acta Paediatrica Scandinavica, (Suppl. 217), 63-67.

Forty-three males were divided into 4 groups and tested for the length of a swimming season on heart rate, oxygen uptake, pulmonary ventilation and while sitting on and when cycling with graduated loads on a bicycle ergometer until subjective exhaustion was reached. Most swimmers were tall and were of medium weight. The fat percentage ranged from 14.2-12.4 and was dependent on age and length of training. Vital capacity increased with age. Maximum pulmonary ventilation increased with age from 65 to 126 l/min. Respiration rate in the young subjects, tidal volume in the older subjects played the major roles in the increased ventilation. In the 13 yr. olds maximal oxygen uptake was 45 ml/min.kg. And for other groups 50 to 51 ml/min. kg. Maximal heart rate ranged from 185 to 190 beats/min. Work capacity at the heart rate of 170 beats/min. increased with age from 148 to 233 W.

Sprunt, J. (1960). Relationship of motor ability and rhythm to achievement in swimming. Unpublished master's thesis, Washington State University.

This study was to determine the extent to which achievement in swimming may be predicted by motor ability or by rhythm. Eighty-one female beginning swimmers were used as subjects. Swimming achievement was measured by performance on the Fox test of side stroke power. The Seashore rhythm test was applied as the measure of ability to detect differences in paired rhythmic patterns. Little relationship between the two variables and the criterion as measured was found.

Sprynarova, S., & Parizkova, J. (1969). Comparison of the circulatory and respiratory functional capacity in girl gymnasts and swimmers. Journal of Sports Medicine, 9, 165-172.

The functional capacity during a load on a treadmill and body composition by estimation of the specific body density were assessed in 10 gymnasts and 10 swimmers. Significantly higher average indicators of the functional capacity in absolute values was found in the swimmer group. A significantly higher amount of lean body mass was found in swimmers, also a significantly smaller ratio of lean body mass, and a significantly greater amount of body fat. Comparison of the aerobic capacity of both groups with data in the literature revealed higher values in these subjects as compared with women not engaged in sports.

Spurgron, J. H., & Sargent, R. G. (1978). Measures of physique and nutrition on outstanding male swimmers. Swimming Technique, 15, (1), 26-32.

This is a descriptive report on the physique and nutrition of outstanding American collegiate male swimmers. Subjects were 47 males who were outstanding 1975-76 college swimmers. Data were obtained for 11 measures of body size, 5 indices of body form, and a measure of body composition. All subjects were examined to ascertain a 24 hour recall inventory and dietary history. Very few of the swimmers followed any long term special diet. Anthropometric data are tabled.

Stager, J. M., Cordain, L., & Becker, T. J. (1984). Relationship of body composition to swimming performance in female swimmers. Journal of Swimming Research, 1, (1), 21-26.

This study was to determine the relationship of body fatness to swim performance in competitive, female swimmers (N=284). Best performance in best event and 100 yd. freestyle was determined by questionnaire. Body composition was estimated by densitometry. Best time in either event was not significantly related to body density, fat percentage, fat body mass or years of competition except in 13 yr. olds. Performance was found to be related to lean body mass. For female competitive swimmers ages 12 to 17, while lean body mass appears to influence swimming performance, body fatness is relatively unimportant.

Stager, J. M., Robertshaw, D., & Miescher, E. (1984). Delayed menarche in swimmers in relation to age at onset of training and athletic performance. Medicine and Science in Sports and Exercise, 16, (6), 550-555.

Competitive female swimmers (N=345) and control subjects (N=549) completed questionnaires concerning general health, athletic training history, and age at menarche. Results indicated that as a population the mean age at menarche of the swimmers (13.4 yrs.) was significantly later than the controls (13.0 yrs.).

Stockholm, A. (1969). The effects of swimming interval training. Swimming Technique, 6, 8-10.

Four highly trained swimmers participated in a training program held

6 days per wk. with 2 sessions totaling about 10,000 M. a day. Each swimmer was tested 4 times during an 8 wk. period at 2 wk. intervals The testing period subjected the swimmers to 30 times 50 M., with 10 sec. rest after each length. Heart rate recordings were obtained. The average swimming time per length for each swimmer decreased at least one and one half sec. during the 8 wks. Breaststrokers had a greater variance than did the front crawlers. Three of the 4 swimmers experienced a slight increase in the number of stroke cycles during the 8 wks.
The swimmers could get a faster time out of the same amount of work, as indicated by the heart rate.

Stoner, L. J., & Luedtke, D. L. (1979). Variations in the front crawl and back crawl arm strokes of varsity swimmers using hand paddles. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 281-288). Baltimore: University Park Press.

This study was done to determine arm pattern differences in 8 college swimmers (4 male, 4 female) as they executed both front and back crawl stroke with and without hand paddles. Film analysis indicated that swimmers who use hand paddles do not seem to make major alterations in either front or back crawl stroke patterns.

Street, R. H. (1958). Cardio-vascular effects of a summer competitive swimming program. Journal of Canadian Association of Health, Physical Education & Recreation, 24, 34-37.

This study was to determine cardiovascular effects of a training program upon summer season competitive swimmers. The experimental group was compared with a group participating in a summer playground program. the Harvard step test was administered to both groups as an initial and final test, with a 6 wk. interval between tests. The competitive swimmers underwent a daily training program during this 6 wk. period while the playground group had only normal playground activities 3 hrs. per wk. There was a positive relationship between the intensity and the duration of training and the modification of pulse rate upon recovery from exercise.

Stroup, F., Harris, A., & McCormick, J. (1967). Anthropometric measurements and swimming performance. Swimming Technique, 4, 13-15.

The purpose of this study was to take selected anthropometric measurements of a large number of outstanding competitive swimmers and to summerize these measurements and compare them with measurements of other groups; and to compare the measurements of swimmers entered in the various events to note any correlation between the various measurements and swimming times in the various events and between the times of swimmers entered in pairs of events. Measurements were taken for 8 characteristics of 142 swimmers who participated in the 1966 college division NCAA swimming meet held at Illinois State University.

The anthropometric measurements of the swimmers indicated that they were larger than known averages for college men. The older, taller and heavier

men tended to swim the short freestyle races. The shorter and lighter men tended to swim butterfly and distance races. Men swimming breaststroke and distance freestyle races tended to have bigger waists and to be heavier for their height than men who entered other events. The times for men entered in two events showed a correlation sufficiently low to make the outcome of the second race unpredictable and therefor to justify races of different distances. Correlations coefficients between swimming time and any anthropometric measurement were not sufficiently high to be of much aid in predicting times.

Stull, G. A., & Thompson, H. L. (1959). Effects of various training programs on speed of swimming. Research Quarterly, 30, (4), 479-485.

Eighty-one male subjects were divided into 6 groups and tested to determine if various training programs affected performance in speed for swimming 30 yds. No evidence of improvement was experienced by one group after 6 wks. of absolutely no exercise and also, after a group of subjects had participated in various weight exercises 3 times a wk. for 6 wks. The 4 other groups showed significant improvement. One of these groups practiced starts, kicking, arm stroking, and sprinting 30 and 60 yds. three times a wk., and another group did the same routine 6 times a wk. Another group was exposed to weight training and swimming and the other was exposed only to 30 yd. sprints and practicing starts. No significant differences were found between these 4 groups.

Swaine, I., & Reilly, T. (1983). The freely-chosen swimming stroke rate in a maximal swim and on a biokinetic swim bench. Medicine and Science in Sports and Exercise, 15, (5), 370-375.

The purpose of this study was to investigate the significance of the freely-chosen stroke rate in swimming to attain maximum velocity. Seven club swimmers swam five 366 M. freestyle trials at increasing velocities. Each subject also performed a maximal test on the biokinetic swim bench where stroke rate was manipulated according to the five rates used by the subjects in the swim trials. Maximum velocity was not significantly correlated with VO2 max. or with VO2 peak on the bench. Results confirm that freely-chosen stroke rate produces the top performance in swimming to attain maximum velocity and the highest peak VO2 values in simulated swimming on the bench.

Swegan, D. B., & Thompson, H. L. (1959). Experimental research in swimming. Scholastic Coach, 28, 22-26.

Summarizes experimental research completed before 1959. Under studies dealing with physiological factors are: Effects of drugs on swimming performance, diet, O2 consumption, cramps, disease, and warm up studies. They review studies on swimming starts, relationship of certain tests to swimming

ability, and stroke analysis. Twenty-three references.

Tews, R. W. (1941). Relationship of propulsive force and external resistance to speed in swimming. Unpublished master's thesis. State University of Iowa.

The purpose of this study was to determine the relationship of resistance and velocity of swimmers and the relationship between propulsive force and swimming velocity of arms alone, legs alone, and full crawl. Twenty swimmers were tested. Measurements were made of propulsive force by means of a kymograph attached to the swimmer by means of a cord. Speed was determined by timing the subject as he swam a 28 ft. course. A block and tackle was used to tow subjects through the water to determine resistance. Propulsive force correlated high with velocity. Correlations for resistance and speed were low. Height and weight of swimmers were the factors revealed which can by used to help determine resistance.

Thompson, H. L. (1958). Effect of warm-up upon physical performance in selected activities. Research Quarterly, 29, (2), 231-246.

Eighty-five male college students were used to test the effect of formal and informal warm-ups on speed and endurance in swimming. No evidence of improvement was found after an informal warm-up, but a formal warm-up did improve performance in speed and endurance in swimming.

Thompson, H. L. (1958). Effect of vigorous swimming on blood viscosity of conditioned subjects. Research Quarterly, 29, (4), 482-483.

Blood viscosity of 34 conditioned male subjects was determined before and after a 300 yd. crawl stroke swim. Results indicated that participation of conditioned subjects in vigorous swimming is not an important factor in causing blood to become more viscous. Vigorous swimming seems to cause an increase in blood viscosity of some conditioned individuals and to decrease the blood viscosity for others.

Thornton, N., & Flavell, E. R. (1979). Power peak training. Swimming Technique, 16, (2), 44-47.

A study of the Cal Berkeley swim team was done to determine the power output characteristics of competitive swimmers. The objective was to develop performance curves for each of 3 competitive strokes and to establish a recommended speed of operation of the biokinetic swim bench for each stroke. The results of over 1000 bouts on the swim bench were averaged for the entire team in each stroke for each of 10 settings on the bench.

Thornton, N., & Flavell, E. R. (1981). Dry-land performance assessment with

isokinetic instrumentation. Biokinetic Strength Training, 1, 17-20. Isokinetics, Inc., Albany, CA.

Sixteen members of the Cal Berkeley swim team (male) were tested for arm power, leg power, vertical jump, on the biokinetic swim bench and the "leaper" leg machine. Results are tabled. Statistical analysis not done. Arm and leg power data found not to correlate well.

Thrall, W. R. (1960). A performance analysis of the propulsive force of the flutter kick. Unpublished doctoral dissertation, University of Iowa.

Tiharnyi, J. (1972). Relationship of selected maturational determinants to competitive swimming. Unpublished doctoral dissertation, University of Alberta.

Tiharnyi, J. (1974). Influence of preliminary warmup on 50 yd. freestyle. Swimming Technique, 10, 122-124.

Five boys ranging from 13-17 yrs. of age, members of an age group swim team, were relatively inexperienced and presumably had no strong commitments for or against warm-up before competition were tested. The warm-up treatments were: swim and shower, swim and rest, resistance exercise and shower, resistance exercise and rest, calisthenics and shower, and calisthenics and rest. No significant differences were varified among the different conditiions.

Tilley, J. L. (1951). Relation of land drills and other tests to speed in swimming. Unpublished master's thesis, University of Illinois.

Timmins, B. L. (1941). Physiologic effects on college women of immersion in water of 65-70 degrees fahrenheit-cardiovascular and respiratory changes. Unpublished master's thesis, Wellesley College.

To determine the physiologic effects on 18 college females of immersion in water of 65-75 degrees F., the followin masurements were made: systolic pressure, diastolic pressure, pulse pressure, pulse rate, respiration rate and respiration depth. Vital capacity and grip strength were measured before and after each immersion. When the body is immersed in water at these temperatures for 15 min. the systolic blood pressure rises, diastolic blood pressure rises, pulse pressure remains unchanged, pulse rate remains unchanged, respiration rate remains unchanged, respiration depth increases and vital capacity decreases as does grip strength. Adjustments are made in the first five min. in 70 and 75 F. degree water but, continue throughout the 15 min. in the 65 degree water. Greasing the body had no effect on these reactions.

Torma, Z. D., & Szekely, G. (1978). Parameters of acid-base equilibrium at various swimming intensities and distances. In B. Eriksson & B. Furberg (Eds.) Swimming Medicine IV (pp.274-281). Baltimore: University Park Press.

This study was an effort to examine the degree of anaerobic work of swimmers with maximal assurance of typical training schedules. The study confirms the existance of alactacid and lactacid phases of anaerobic metabolism, postulated by Margaria, Edwards, and Dill (1933), by the use of a simple workload model of short term swimming performance.

Treffene, R. J. (1978). A method of predicting swim performance time using heart rate measurement in the pool. International Swimmer, 14, (7), 15-17.

A chart containing predicted performance data for 20 swimmers was determined mathematically from the swimmers best 100 and 200 yd. times. In most cases the agreement was excellent except that some of the younger swimmers had slower than predicted times. This technique was suggested for determining training goals and for tapering programs.

Treffene, R. J. (1978). Swimming performance test. A method of training and performance time selection. Australian Journal of Sports Medicine, 10, (2), 33-38. Reprinted (1979). Swimming Technique, 15, 120-124. Reprinted (1978). The International Swimmer, 15, (5), 15-18.

A technique for prediction of performance in swimming from the maximum heart rate, the target time, and the swimming time of an all out 100M. swim was proposed. Prediction equations are presented.

Treffene, R. J. (1981). Heart rate measurement technique in swimming training and performance control. International Journal of Sports Medicine, 2, 276.

Twenty-four swimmers training for international competition in a training camp were studied during training sessions to determine changes in heart rate for controlled speeds. Records of heart rate immediately following controlled swimming performance over 200M. or more were recorded and graphs of heart rate versus speed were determined. A specially designed instantaneous beat by beat monitor was used for all heart rate measurements. Those swimmers undergoing at least 15 min. continuous type training showed significant changes in the graph. Use of results was made in determining training schedules and prediction times for endurance events including two world records. All predictions were within 1% of actual times swum. Measurement of lactic acid 3 min. after swims at different speeds indicated that endurance swimmers reached low values and sprint swimmers high values at the speed at which maximum heart rate is first reached. Thus sprint swimmers cannot use the same prediction equation as for endurance swimmers.

Treffene, R. J., & Alloway, J. (1977). Determining swim efficiency using heart rates. International Swimmer.

Treffene, R. J., Alloway, J., & Jull, J. (1979). Use of a heart rate meter in swimming and athletic performance measurement. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 275-280). Baltimore: University Park Press.

This study was directed at using a heart rate meter constructed for measurement in the pool to determine the velocity heart rate curves for swimmers. Heart rates were measured at rest and after 2 or 3 controlled and after maximum swims. The relationship between heart rate and freestyle swimming velocity are shown.

Treffene, R. J., Alloway, J., & Shaw, J. (1978). Use of heart rates in the determination of swimming efficiency. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 132-136). Baltimore: University Park Press.

At low submaximal swimming speeds 15 male and 15 female swimmers displayed a definite linear velocity-to-heart rate relationship. It continued through to maximum heart rate for some. For others, however, a radical change in gradient occured, indicating a change in efficiency caused by a breakdown in swimming form.

Treffene, R. J., Craven, C., Hobbs, K., & Wade, C. (1979). Differences in sprint and endurance swimmer's plasma lactate and heart rate responses in controlled swims. Swimming Technique, 16, (2), 34-36.

Eleven swimmers training for international competition had heart rates recorded immediately following controlled swimming performance at constant speeds over 200M. Measurement of lactate levels 3 min. after swims at different speeds were used to calculate the expected blood lactate value for each swimmer at the speed at which maximum heart rate is first reached. Endurance swimmers had low values (8.8 M Mol/1) and most sprinters had high values (12 M Mol/1) at their target time speed.

Treffene, R. J., Dickson, R., Craven, C., Osborne, C., Woodhead, K., & Hobbs, K. (1980). Lactic acid accumulation during constant speed swimming at controlled relative intensities. Journal of Sports Medicine, 20, 244-254.

Rates of lactic acid accumulation during constant speed swimming were calculated for various relative swimming intensities between 86% and 110% of the Treffene V max. speed. At speeds below this measure the rate of lactic acid accumulation was less than 0.55 mmol/l/min. When V max. speed (the minimum speed at which the maximum heart rate and therefore maximum O2 uptake occurs) is exceeded, the rate of lactate accumulation exceeds 1.0 mmol/l/min. The rate increases rapidly as speed increases above V max.

The speed at which the anaerobic threshold (AT) occured was calculated for each of the 47 trained swimmers. The AT occured at an average of 95.6% V max. while a marked change in the rate of lactate accumulation above 100% V max. A theoretical explanation of the increased rate of lactate accumulation above V max. speed is proposed along with implications for control of training and performance of swimmers.

Treffene, R. J., Frampton, C., Tunstall-Pedoe, D., & Idle, M. (1976). The energetics of swimming using heart rate telemetry. Annual Proceedings of Australian Sports Medicine Conference, Brisbane.

Troup, J. P., Plyley, M. J., Sharp, R. L., & Costill, D. L. (1981). Development of peak swimming performance: Strength training and tapering. International Journal of Sports Medicine, 2, 276.

To determine the benefits derived by performance with a 4 mo. strength training program accompanied by periods of reduced workloads (taper), 15 male swimmers (14-30 yr.) were matched into 3 groups which comprised swimming only, swimming and weight training, and weight training only. Testing was done at pre-season, 4 times during the season and 3 times during the 3 wk. taper. Maximal upper body strength was recorded as power during a maximal arm pull at speeds on an isokinetic swim bench. Although differences in power between the groups were seen, they were not significant. Power during the taper in each group did not significantly differ from earlier peak values.

Turkington, H. D. (1959). A comparative study of an interval and a traditional method of training for competitive swimming. Unpublished master's thesis, Washington State University.

This study was to determine if there was a difference in the performance of experienced swimmers following certain prescribed methods of training. Eighteen varsity swimmers participated in a 3 wk. conditioning session of prescribed calisthenics and distance swimming then they were divided into two groups of interval and traditional practice routines. Groups trained for 22 periods over 5 wks. The traditional group had swimming with arms only, legs only, and combined stroke. The interval group swam ten paced out 100 yd. with a 3 min. rest between each. There was no significant difference between the performance of the two groups.

Twardowski, E. T. (1962). The effect of warm-up upon 100 yard swimming performance. Unpublished doctoral dissertation, Temple University.

This study was to determine the relationship between selected types of warm up procedures and subsequent 100 yd. crawl stroke swimming performance of 25 varsity swimmers. The warm up procedures were : 1. Formal warm up of calesthenics and swimming. 2. Hot shower bath warm up for 8 min. 3. Hot whirlpool bath warm up for 4 min. And 4. No warm up. It was found

that swimming performance in the 100 yd. crawl stroke is improved when preceded by formal warm up . Active warm up can be effective in improving swimmers performance. Swimming performance in the 100 yd. crawl stroke is more effective after no warm up than after the hot shower or hot bath warm ups.

Vaccaro, P., & Clarke, D. H. (1978). Cardiorespiratory alterations in 9- to 11-year old children following a season of competitive swimming. Medicine and Science in Sports, 10, 204-207.

Vaccaro, P., Dummer, G. M., & Clarke, D. H. (1981). Physiological characteristics of female master's swimmers. The Physician and Sportsmedicine, 9, 75-78.

Two female masters swimmers, ages 70 and 71, were compared with sedentary females of the same age and with younger female athletes. They had considerably lower percent body fat than normal sedentary women in their 70's and were well within the range for normal women 19 to 25 yrs. old. Their VO2 max. values were about twice those for normal women in their 70's and comparable to considerably younger nonathletes. These findings show that regular physical training may delay the accumulation of excess fat that accompanies inactivity during aging and may also offset the age related decline in aerobic power.

Vaccaro, P., Ostrove, S. M., Vandervelden, L., Goldfarb, A. H., Clarke, D. H., & Dummer, G. M. (1984). Body composition and physiological responses of master's female swimmers 20 to 70 years of age. Research Quarterly for Exercise and Sport, 55, (3), 278-284.

Eighty-seven female master's swimmers ranging in age from 20 to 69 were selected for a study of their body composition and physiological responses at rest and during exercise. Significant differences were shown when comparing the highly trained group to the not highly trained group on measures of weight, body density,percent fat, lean body weight and VO2 max. In both groups percent fat across age levels within each training group showed significant increases at about age 40. It appears that the rate of decline in VO2 max. in women with aging may be independent of training status.

Van Der Helm, F. C. T., Toussaint, H. M., Elzerman, J. R., de Groot, G. J. Van Ingen Schenau, G. J., & Hollander, A. P. (1982). A power balance approach to swimming. The V International Congress on Biomechanics and Medicine in Swimming.

Elite Dutch female swimmers of Olympic caliber were measured against top national-level swimmers. Although a 10% difference existed in performance level, no significant difference was found in VO2 max. or external power, as measured during arm and leg work on a bicycle ergometer. A significant difference was found when the two groups arm length

and hand surface area was compared. These two parameters showed a high correlation with the swimmers stroke length and swimming speed, whereas the physiological parameters did not.

Van Handel, P. J., Cells, K. A., Bradley, P. W., & Troup, J. P. (1984). Nutritional status of elite swimmers. Journal of Swimming Research, 1, (1), 27-31.

Observations were made to determine whether any nutritional dificiencies exist in the diet of competitive swimmers. Highly trained, elite female (N=14) and male (N=13) swimmers had their diets surveyed over a 3 day period. Observations suggest that on an average basis, while non-caloric nutients may be obtained in adequate amounts, these athletes may not be providing optimal levels of energy producing foods. Individual athletes may have extremely poor dietary habits and as a result have severe nutrition problems.

Van Huss, W. D., & Cureton, T. K. (1955). Relationship of selected tests with energy metabolism and swimming performance. Research Quarterly, 26, 205-221.

Forty-one varsity swimming team candidates were tested using a battery of 52 swimming, cardiovascular, and energy metabolism measures. Multiple regression analyses were completed to select the most representative measures of each of the criteria of each of the testing areas. Further multiple regression analyses were done to determine the relative importance of the measures to 100 yd. and 440 yd. swimming performance. Results show the abilities measured by the Cureton diagnostic swimming tests are relatively more important to 100 yd. and 440 yd. swimming performance than the capacities measured by the cardiovascular and metabolic tests. The capacities measured by the gross oxygen debt and the 100 yd. drop-off test are of more relative importance to 100 yd. than 440 yd. swimming performance. The capacities measured by the gross oxygen intake and the legs alone 60 ft. test and 24-ft. glide time swimming tests are of more relative importance to 440 yd. than 100 yd. swimming performance. The metabolic, cardiovascular, and swimming tests in combination relate better generally to 440 yd. than 100 yd. swimming performance.

Vasar, E., & Laidre, H. (1975). Usage of apnea technique in endurance training. Swimming Technique, 12, (1), 8-32.

This study was to find out the effects of breath holding on 16 pentathlon competitors preparing for the swimming event. The technique was used out of water, combined with stationary running. Control swims showed significant improvement in 300 and 800 M. distances.

Vervaecke, H. U. B., & Persyn, U. J. J. (1979). Effectiveness of the breaststroke leg movement in relation to selected time-space, anthropometric, flexibility, and force data. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 320-328.). Baltimore: University Park Press.

This study was done to determine (with ordinary swimmers) how much the propulsion possibilities of the legs in the breaststroke are influenced by certain anthropometric and motor abilities, especially flexibility. Cinematographic data of good subjects during a pulling force test showed that they used external rotation, supination, and flexion much more than the poorer subjects.

Vogie, R. D., & Deutsch, D. T. (1983). Anaerobic contribution to multi-event sprint swimming. Medicine and Science in Sports and Exercise, Abstracts, 15, (2), 161.

Male (N=6) collegiate swimmers performed three 100 yd. freestyle swims, each separated by a 30 min. recovery; in a trained state at the end of the competitive season, a detrained state following a 4 wk. inactivity, and a retrained state after 4 wks. of sprint training. Measures were the alactic O2 debt, blood lactate differences, and performance time. It was concluded that a 4 wk. inactivity decreases anaerobic contribution to performance and increases performance time. Four wks. of retraining will result in only improved glycolytic contribution to anaerobic metabolism, and performance time similar to those at the end of the competitive season.

Wade, C. E. (1976). Effects of a season's training on the body composition of female college swimmers. Research Quarterly, 47, (2), 292-295.

College female swimmers (N=15), mean age 18.6 yr., were assessed for body composition and skinfolds at the beginning and end of 9 wks. of competitive training. A significant increase in body density resulted in significant decreases in absolute body fat. Skinfolds of the triceps, suprailiac, and subscapula decreased significantly, suggesting the fat loss was mainly subcutaneous. The relation of these body composition changes to body insulation and sinking force while swimming are discussed.

Wagner, L. F. (1954). Effects of immersion and exercise in water on the cardiac output. Unpublished master's thesis, University of Illinois.

The purpose of this study was to investigate the effects of immersion and exercising in water on the cardiac output of 3 subjects. Subjects were tested while lying on the edge of the pool, while submerged in water, and while exercising in the water. Minute volume increased after 25 min. of immersion. Minute volume increased after exercising in the water for 16 min.

Stroke volume increased after 25 min. of immersion and after exercising in water for 16 min. From the lying in water state to exercising in water both minute volume and stroke volume increased.

Wellington, G. (1914). Effect of swimming upon heart rate, weight and body temperature. Unpublished master's thesis, Springfield College.

The purpose of this study was to observe 5 men swimming 440 yds. or more. Heart rate was taken before and after in vertical and horizontal positions, weight variations and temperature variations were observed. Swimming increased the heart rate taken in both horizontal and vertical positions. Swimming 440 yds. increased the heart rate, but this increase was reduced over 50% five min. after swimming. A slight amount of weight was lost. No conclusion was made concerning changes in body temperature while swimming.

Weswig, P. H., & Winkler, W. (1974). Iron supplement and hematological data of competitive swimmers. Journal of Sports Medicine, 14, 112-119.

Seven varsity swimmers were given iron supplement while 7 others received placebo during 5 mo. of intensive training. Twelve non-athletes served as a control. It was concluded that ingestion of the iron supplement did not significantly affect the hematological and associated iron and copper content of blood following strenuous exercise.

White, J. R. (1964). Food habits of male high school swim team members during the swimming season. Unpublished master's thesis, University of Iowa.

This study was to assess the eating habits of male high school competitive swimmers during the swimming season. A questionnaire was sent to 103 competitive swim team members concerning their diet during the swimming season. It includes an analysis of food consumed, frequency of between meal snacks, and classification of subjects. About 70% of subjects did not eat a special breakfast on the morning of the meet. About 50% took vitamins or energy pills during the swimming season and about 45% took them during the year. About 55% ate a special meal some hours before the meet. About 88% ate this meal 2 to 4 hours before swimming. About 63% indicated that special foods such as fruit, honey, sugar, jello eggs, wheat germ and tea were taken during the season. Some 88% included fruit, honey, sugar, jello, eggs and wheat germ. The same percent who ate special foods ate them between one-half to 3 hrs. before the meet. About 42% ate between their swimming events. No significant differences between the mean caloric intake of older swimmers on the day of the meet and during the 4 days before the meet was found. All ate significantly less calories on the day of a meet than they did on the average of the 4 days before the meet.

Wielt, H., Jr. (1914). Heart rate in relation to swimming. Unpublished master's thesis, Springfield College.

The purpose of this study was to determine the effect of swimming on the heart rate, compare it with other sports and heavy weight lifting or exercise of maximum effort. Events that necessitated speed and endurance caused the highest increase in heart rate of the 100 swimmers observed. Speed, nervous tension and endurance were the chief factors in raising heart rate. Influence on the heart rate was less in both 100 and 440 yd. swims than on 100 and 440 yd. running dashes. The 200 yd. swim had the greatest effect on heart rate increases. The 440 distance influenced the pulse rate least of the 440, 500 and 1000 yds. swims. The 1000 yd. swim influenced pulse rate most. Speed alone did not necessarily indicate a high increase in heart rate.

Wilk, E. R. (1956). Study to determine the relationship between increase in strength of the muscles involved in crawl stroke swimming and speed in swimming the crawl stroke for a distance of 40 yards. Unpublished master's thesis, Springfield College.

This study was to determine the relationship between an increase in strength of the muscles involved in crawl stroke swimming and time required to swim the crawl stroke for a distance of 40 yds. Thirty varsity swim team members were equated into two groups based on a 40 yd. time trial. The experimental group had a 4 wk. weight program to increase the strength of the shoulder extensor muscles responsible for the propulsive phase of the crawl arm stroke. It was found that increase in speed in swimming the crawl stroke for the 40 yd. distance was possible through an increase in strength of these muscles by use of a weight training program.

Williams, M. H., & Jackson, C. W. (1979). Specificity of training related to muscular endurance. Swimming Technique, 16, (1), 28-32.

The purpose of this study was to investigate the effect of 3 different training methods upon tests of muscular endurance and characterized as anaerobic tasks. Sixty male university students of general physical fitness classes were subjects. Only 47 completed the full experiment. Results are tabled and support the concept of specificity of training relative to the development of anaerobic work capacity.

Woods, M. D. (1958). Effectiveness of an endurance swimming program on the physical fitness of college women as related to cardiovascular condition, physique and motor fitness. Unpublished master's thesis, Womens College of the University of North Carolina.

This study was to determine if endurance swimming would alter systolic and diastolic blood pressures, blood sugar concentration and hemoglobin concentrations. Cardiovascular condition, motor fitness and physique were also measured on 10 college women of intermediate swimming ability. At the pre-exercise level the lower arterial pressures were accompanied by a

greater body weight, motor fitness score and total subcutaneous fat deposits. After exercise diastolic pressure after training and systolic pressure before training were accompanied by higher sugar concentrations.

Yancher, R., Larsen, O., & Baer, C. L. H. (1984). Sprint recovery time. Swimming Technique, 20, (3), 27-28.

To test for recovery times following sprinting, 13 swimmers did maximal 15 sec. sprint repeats from pushoff and results recorded in pounds of force exerted. Average recovery time was 1 min. and 40 sec. Range was 1 to 3 min.

Yashizawa, M., Torkurjama, H., Okamoto, T., & Kumamoto, M. (1976). Electromyographic study of the breaststroke. In P. Komi (Ed.), Biomechanics V-B (pp. 222-229). Baltimore: University Park Press.

Yost, M. M. (1949-1950). Effect of 100 percent oxygen inhalation on performance recovery in swimming. Abstacts of Doctoral Dissertations, 505-509.

Zauner, C. W., Fencl, J., & Page, B. J. (1973). Physiological characteristics of age-group swimmers. Florida Association for Health, Physical Education, and Recreation Workshop Papers, Miami Beach, Florida.

Zauner, C. W., Fencl, J., & Swenson, E. W. (1974). Physiological characteristics of young, well-trained female swimmers and runners. Medicine and Science in Sports, Abstracts, 6, (1), 87.

This study was designed to assess physiologic functions in young female athletes successful in competition at state, regional, national and international levels. Six well trained female swimmers and 4 similarly conditioned female runners were measured for forced vital capacity, forced expired volume in 1 sec., total lung capacity, pulmonary diffusing capacity, peak expiratory flow, maximal voluntary ventilation, maximal oxygen uptake and physical work capacity. Lung clearance index was also derived. Also the best 5 male and female performers from an AAU age group team were also evaluated and then compared. The observed mean FVC for female swimmers and runners was significantly greater than that predicted on the basis of size, age and sex. The observed LCI was significantly smaller than predicted. Mean PEF, MVV, and PWC were large but mean max. VO2 was not especially so considering the state of training. Except for LCI, all means achieved by male age group swimmers were larger than those for the females. Mean LCI was smaller for male as opposed to the female swimmers. These differences were not significanly different. All athletes demonstrated reduced LCI, suggesting superior air mixing capability of their lungs.

Zauner, C. W., Kaufman, D. A., & Benson, N. Y. (1977). Effect of protein dietary supplement on body composition of swimmers. Swimming Technique, 13, 120-122.

This study tried to determine whether supplementing the diet of young competitive swimmers with all essential amino acids augments the hypertrophy of training. Eighteen age-group swimmers involved in a typical competitive program were selected and matched on the basis of sex and for approximate size and age so that 9 pairs were formed. One randomly selected member of each pair took 30 grains of dietary protein supplement daily. Controls continued training and maintained constant all other aspects of their lifestyles and all subjects were involved in running, swimming and resistance training. Final measurements were made 3 mo. subsequent to start of dietary supplementation. Both groups gained body weight, and although the experimental group became leaner than the control group their mean reduction in percent body fat was not statistically significant.

Zir, L. M., Rahe, R. H., Rubin, R. T., & Arthur, R. J. (1972). Effects of strenuous swim competition in the older age group. Journal of Sports Medicine, 12, 183-185.

Physiological and biochemical measurements were made of older,2-56, male swimmers in the first U.S. National master's swimming championship. There was a significant drop in subjects post-swimming systolic and diastolic blood pressures, a post-swim tachycardia was also seen. No ST, T-wave, or rhythm changes were noted in subjects post-swimming electrocardiograms. There were significant post-swimming elevations in subjects serum uric acid and cholesterol concentrations. In general these swimmers seemed to have high baseline levels of serum uric acid and low baseline level of serum cholesterol.

Mechanical Aspects

Adams. T. M. (1979). A cinematographic analysis of a single underwater front crawl armstroke. Unpublished master's thesis, East Carolina University.

Adams, T. A., Martin, R. B., Yeater, R. A., & Gilson, K. A. (1983). Tethered force and velocity relationships. Swimming Technique, 20, (3), 21-26.

This study evaluated the interrelationships among tethered force, stroke rate, and velocity in 9 male and 9 female college varsity swimmers in the front crawl stroke. The experiments confirmed a negative linear relationship between tethered force and release velocity. No significant differences between the sexes was observed.

Adrian, M. J., & Ringer, L. B. (1969). An electrogoniometric study of the wrist and elbow in the crawl arm stroke. Research Quarterly, 40, (2), 353-363.

Eighteen subjects, from varsity swim teams (trained), and from swimming classes (untrained) were tested for flexion and extension patterns of the wrist and elbow joints during the crawl stroke. Each swam 20 yds. from a dead start 4 times. The wrist and elbow actions were recorded by means of water-proofed electrogoniometers attached to both wrists and elbows, which measured continuously the angles and recorded them on an escillograph. Water-proofed tranducers placed on each palm recorded on the escillograph the instant of hand entry and exit from the water. It was found that the overall patterns of movement were similar. However, there were differences between the trained and the untrained groups. The varsity group showed greater extension of the elbow at entry and at exit, greater extension of elbow in the first part of underwater portion of stroke, and greater angular velocity of elbow flexion and extension, with extension producing the greater angular velocity.

Allen, R. H. (1948). A study of the leg stroke in swimming the crawl stroke. Unpublished master's thesis, State University of Iowa.

This study analyzed the factors of the propulsive force of the leg kick in the crawl stroke. Twenty-two trained swimmers were tested with 4 different types of kicks. They were normal, narrow, medium and wide kicks. The slower the kick, the less it contributed to the propulsion of the whole stroke and the faster the speed of the kick, the more it contributed to the whole stroke. The narrow kick was superior to the medium and to the wide kick.

Alley, L. E. (1952). Analysis of water resistance and propulsion in swimming crawl stroke. Research Quarterly, 23, 253-270.

An analysis of water resistance and propulsion in swimming the crawl found that a bow wave of comparatively small magnitude was observed at the 5 ft/sec. velocity. At 6.4 ft/sec. the wave had increased to the extent that it increased the drag. He concluded that the bow wave was an inportant factor in limiting swimming speed. At each velocity for which force was measured, the mean for the whole stroke using the normal arm stroke and kick was greater than the means for the other strokes. At each velocity measured the mean for the normal arm stroke was greater than the mean for the bent arm stroke. As velocity becomes greater a decrease in force is noted which is greater than can be attributed to drag.

Alteveer, R. J. G. (1958). A natographic study of various swimming strokes. Unpublished master's thesis, Springfield College.

The purpose of this study was to analyse speed variations within a single cycle of the breaststroke, the butterfly stroke with the frog kick as well as with the dolphin kick, and the crawl stroke, and the back crawl.

Six varsity swimmers were tested on the natograph and the results were compared with data obtained in previous tests on 5 other subjects. More than 100 recordings on the natograph were used. The back crawl and crawl had the most uniform speed, the butterfly-frog was the most fluctuating in speed. The butterfly-dolphin reached the highest momentary speed.

Andersen, P. (1976). The use of hand paddles, overload training and after effects. Swimming Technique, 13, (2), 58-62.

Not an experimental study, but a review of studies on overload training concluding that for highly skilled swimmers, paddles have little effect on pattern development and later performance. Errors in position should be easily detected with beginner swimmers.

Armbruster, D., Morehouse, L., & Tuttle, W. W. (1939). The use of starting blocks in swimming sprints. Research Quarterly, 10, 89-92.

Data were collected from 18 well-trained varsity swimmers. The evidence showed quite conclusively that starting blocks are a disadvantage to swimmers in leaving the mark at the start of a swimming race, as far as starting time is concerned. Starting time was defined as the interval between the pistol shot and the time the swimmer leaves his mark.

Ashcraft, R. J. (1960). A comparative study of two styles of racing starts in swimming. Unpublished master's thesis, Macmurray College.

This study was to determine from which style of racing start, the freestyle or breaststroke, a swimmer could obtain the greastest distance in the shortest interval of time by comparing the performance of 33 swimmers on 2 styles of racing starts. One with arms starting from a relaxed, hanging position in front of the legs and the 2nd starting from an extended arm position behind and above the body and moving down and forward on the take-offF. It was concluded that the 2nd position was better because a greater distance was achieved in a shorter time interval.

Ayalon, A., Gheluwe, B. V., & Kanitz, M. (1975). A comparison of four styles of racing start in swimming. In J. P. Clarys & L. Lewille (Eds.) Swimming II (pp. 233-240). Baltimore: University Park Press.

The purpose of this study was to compare 4 styles of swimming racing starts: 1) conventional style, 2) grab start, 3) bunch start, and 4) track start. Twenty untrained male swimmers were taught the 4 styles of start. Film analysis indicated that the bunch and track styles were faster in leaving the blocks. Time in the air was similar in all styles. The bunch start was slowest in reaching the 5M. line.

Bachman, J. C. (1969). A comparison of hand positions in swimming freestyle. Swimming Technique, 6, (3), 72-73.

Plaster casts were made of 4 hand positions: hand flat with fingers open, hand cupped with fingers open, hand flat with fingers together, hand cupped with fingers together. Trials, (total of 625) were made by pulling the hand cast through a tank of water using a tension spring. Results showed no statistically significant differences between hand positions used.

Bachman, J. C. (1983). Three butterfly pulls. Swimming Technique, 20, (1), 23-25.

To determine the effectiveness of 3 different types of arm pulls in swimming the butterfly stroke, 42 accomplished swimmers were tested on the strokemeter. The distance each subject was able to pull himself in the water from a stationary position using the different pulls was measured. The double "s" curve pull and the sculling pulls were significantly better than the straight pull, but did not differ from each other. A significant correlation was found between a 20 yd. butterfly swim time and the double "s" curve strokemeter results.

Bandy, J. A. (1951). A study of the relationship of the front crawl flutter kick and the drag. Unpublished master's thesis, State University of Iowa.

This study was to investigate the problem of resistance and propulsion in the execution of the flutter kick. Towing force and drag were determined for 9 subjects over a velocity range of 3.26-6.55 ft./sec. The maximum free kicking velocity and maximum free whole stroke velocity were also determined. An attempt was made to determine the relationship between the factors measured. The towing forces of 7 subjects out of 9 were less than the drags between the velocities of 4.54 and 6.55 ft./sec. With 2 subjects the drag was less than towing force. The drag and towing force of 9 subjects had the greatest increase between 5.83 and 6.55 ft./sec.

Barthels, K. M. (1974). Three dimentional kinematic analysis of the hand and hip in the butterfly swimming stroke. Unpublished doctoral dissertation, Washington State University.

Three male and 3 female intercollegiate competitive swimmers performed dolphin butterfly stroke with and without the kick. Motion of the right hand was recorded simultaneously on the front and side view films. The cinematographic data were analyzed by computer methods. Differences and similarities between male and female performers and between performances in the kick and no-kick conditions were identified. The relationships of three dimentional component hand velocities to coincident horizontal body motion in the no-kick condition were identified, and inferences were made regarding the type of force produced by the hand motion. Stroke velocities were greater for the male subjects than for the females in both conditions.

Barthels, K. M., & Adrian, M. J. (1970). Variability in the dolphin kick under four conditions. International Symposium on Biomechanics, Proceedings.

Electrogoniometry and electromyography were used while subjects swam, legs only with a kick board at full warm-up cadence, legs only with a kickboard at sprint cadence, and full stroke at warm-up cadence, and full stroke at sprint cadence. Differences were discussed.

Barthels, K. M., & Adrian, M. J. (1975). Three-dimensional spatial hand patterns of skilled butterfly swimmers. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp. 154-160). Baltimore: University Park Press.

The purpose of this investigation was to identify the three-dimensional underwater motion of the hand with respect to still water during performance of the butterfly stroke, with and without the kick, and to relate this motion to the horizontal motion of the swimmers body. Displacement patterns are shown through analysis of film on 3 female subjects. A common pattern is noted.

Beckett, K. D. (1985). Pulling a fast one. Swimming Technique, 21, (4), 27-29.

The purpose of this study was to attempt to determine the better of two methods of exiting the flip turn. Forty-eight subjects were tested and the results indicated that the two-arm pullout method of performing the exit phase of the front crawl somersault turn is superior to the one arm pullout.

Belokovsky, V. V. (1971). An analysis of pulling motions in the crawl arm stroke. In L. Lewillie & J. P. Clarys (Eds.), First International Symposium on Biomechanics in Swimming, Proceedings (pp. 217-221). Brussels: Universite Libre de Bruxelles.

This study was undertaken to investigate the pulling motions of the arms during the sprint crawl stroke by classifying different types of pressure against the palms. Fifty-seven subjects swam 100 M. with transducers fixed to the wrist. Three distinct types of strokes were delineated.

Bengtson, E., & Butler, A. (1956). An analysis of the back crawl and the crawl arm strokes. Unpublished master's thesis, Springfield College.

Bloom, J. A., Hosler, W. W., & Disch, J. G. (1978). Differences in flight reaction and movement time for the grab and conventional starts. Swimming Technique, 15, 34-36.

The objective of this study was to determine if any differences existed between the titled starts in the variables of reaction time, movement time

and flight time. Thirty female college non-competitve swimmers were trained and starts then recorded on videotape and then analyzed. The grab start produced faster times on each of the variables measured. The only significant difference occured on the movement time favoring the grab start.

Bober, T., & Czabanski, B. (1974). The influence of different swimming speeds on changes in the technique of the breaststroke. Performance Sports, 12, 4-8. (Polish).

Bober, T., & Czabanski, B. (1975). Changes in breaststroke techniques under different speed conditions. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp. 188-193). Baltimore: University Park Press.

Using a single Polish national record holder in the breaststroke, film analysis on the technique of the breaststroke cycle indicated that change in speed during the stroke is related mainly to the change in time of the glide phase. The slower the swimming the longer the glide.

Bockman, T., Jr. (1951). The correlation of thirty-seven tests with the 100 yard drop-off test in swimming. Unpublished master's thesis, University of Illinois.

The purpose of this study was to examine the relationship between Cureton's 100-yd. drop-off index and 37 other tests on 31 swimmers. The tests that correlated significantly with the drop-off index were the 440 yd. swim, underwater swim for distance, underwater swim time, 60 ft. swim legs alone, gliding time for 24 ft., 60 ft. swim arms alone, the coordination index and the side leg raises with the left leg.

Borowski, S. S. (1972). A comparative analysis of world class backstrokers. Swimming Technique, 9, 49-64.

A comparison of the mechanical similarities and differences of various stroke patterns and positions as demonstrated by a select group of 9 world class backstrokers. Six major stroke characteristics were analyzed: body roll, hand entry, s-curve pattern, head position, amount of air carried, and maximum arm flexion. Their was a strong tendency for the subjects with faster 100 yd. times to have increased arm flexion along with a greater degree of body roll compared with those who would be better at the 200. Similarities between certain sprinters and distance backstrokers were observed.

Bowers, J. E. (1973). A biomechanical comparison of the grab and conventional sprint starts in competitive swimming. Unpublished master's thesis, Pennsylvania State University.

See Bowers, J. E., & Cavanagh, P. R. (1975) for brief annotation.

Bowers, J. E., & Cavanagh, P. R. (1975). A biomechanical comparison of the grab and conventional sprint starts in competitive swimming. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp. 225-232). Baltimore: University Park Press.

The purpose of this investigation was to determine through the use of cinematographic techniques whether differences existed between the grab and conventional sprint starts as used by 6 female competitive swimmers. The group showed shorter mean values when using the grab start in time spent before first movement and time spent on the blocks following the gun flash. It appears that the swimmer is able to leave the blocks more quickly without a decrease in velocity at take-off using the grab start.

Bucher, W. (1975). The influence of the leg kick and the arm stroke on the total speed during the crawl stroke. In L. Lewillie & J. P. Clarys (Eds.), Swimming II (pp. 180-187). Baltimore: University Park Press.

The purpose of this investigation was to evaluate the relative effectiveness of the leg kick and arm stroke on the speed of crawl stroke swimmers. Seventy-six swimmers were divided into three groups depending on ability. They swam 15 M. with legs alone, arms alone and full stroke. Results are tabled. They showed that the arm stroke alone enabled good swimmers to obtain 91%, average swimmers 90%, and poor swimmers 90% of their crawl stroke speed. Most swimmers do not show great deviations in the performance of partial movements.

Butt, C. (1956). Mechanics and kinesiology of the butterfly (dolphin) breaststroke. Unpublished master's thesis, Springfield College.

Cake, F. (1942). The relative effectiveness of two types of frog kick used in swimming the breaststroke. Research Quarterly, 13, (2), 201-204.

Eleven experienced swimmers and 39 inexperienced swimmers were used to study the differences of the conventional frog kick and the new whip kick while swimming breaststroke. Results showed that the whip kick was better in force, speed, and economy than the conventional kick, and no evidence was found that it is more difficult to learn.

Calb, A. R. (1972). Evaluation of the relative contribution of selected mechanical variables to the propulsive phase of the take-off of the racing start in swimming. Unpublished doctoral dissertation, University of Southern California.

The purpose of this study was to evaluate the relative contribution of

selected mechanical variables to the propulsive phase of the take-off of the racing start in swimming. Cinematographic records and forces in the vertical and horizontal axes were obtained of the swimmers. The grab start is mechanically different than the straight backswing and the circular backswing starts. The contribution of variables to the initial velocity of the center of gravity in the propulsive phase of the racing start cannot be established in a general way.

Carpinter, P. J. (1968). Freestyle swimming turns: An investigation into the optimum instant for the resumption of stroking and kicking. New Zealand Journal of Health, Physical Education and Recreation.

Five Olympic swimmers did not resume swimming until some time after the optimum point for continuation of maximum velocity.

Cavanagh, P. R., Palmgren, J. V., & Kerr, B. A. (1975). A device to measure forces at the hands during the grab start. In J. P. Clarys & L. Lewillie (Eds.), Swimming II (pp. 43-50). Baltimore: University Park Press.

The purpose of this study was to design, construct, and make a preliminary evaluation of a device to measure the forces exerted by the hands during the performance of the grab start in competitive swimming. After preliminary testing the device seems to present a valid and objective technique for determining the action of the hands during the grab start.

Cavill, M. J. (1972). A mathematical and cinematographical analysis of propulsive effects in the dolphin butterfly. Unpublished master's thesis, University of Wisconsin.

This study was to determine the relative contributions of the dolphin butterfly stroke. Application was made of a mathematical model to the filming of one subject swimming the butterfly. The arm pull accounted for 92% of the volume of water that was moved backward during the complete stroke cycle, the kick for just 8%. The first kick downward by the legs is larger and moves more water than the second kick.

Chadwick, A. W. (1967). A cinematographical analysis of ten breaststroke swimmers, including certain strength and anthropometric measures. Unpublished master's thesis, Michigan State University.

Selected strength, flexibility and anthropometric measures were recorded; cyclic velocity, stroke coordination, and body positions were measured from film of 10 swimmers of varying ability. Speed was increased when the swimmer's cyclic velocity remained fairly constant; when breathing occured late in the arm pull; and when the arm pull was efficient and powerful enough to result in a high arm velocity. Speed was decreased when the glide was so long that the velocity decreased significantly; when the hip flexion angle at the end of the leg recovery approached 90 degrees creating drag; and with poor body

streamlining. Measures essential to an outstanding swimmer were good ankle flexion, good foot outward rotation flexibility, high leg adduction strength, high leg abduction strength, high knee extension strength, high latissimus strength and high arm pronation strength.

Clarys, J. P., Jiskoot, J., & Lewillie, L. (1976). A kinematographical, electromyographical, and resistance study of water polo and competition front crawl. Swimming Technique, 13, (3), 90-92.

The purpose of this research was to study the biomechanical, anatomical and resistance phenomena of the competitive and water polo front crawl; and to describe similarities and differences; and then to compare the absolute resistance of water on the body positions and movements for both styles of swimming. The kinematographical analysis show important differences in the body position. The polo stroke is characterized by a lordosis and an elevation of the shoulders. Biomechanically, the arm movement patterns are very similar and the brachial biceps works in the same way and at the same moment in both crawl strokes.

Collins, P. A. (1968). A film analysis of selected swimming stroke kicks. Unpublished doctoral dissertation, University of Iowa.

This study was to describe and compare certain aspects of the mechanics of advanced swimmers performing the flutter kick, side stroke kick, and breaststroke kick. Twelve men from the varsity swimming team and 13 women participated for underwater films and overhead films of the strokes. Faster swimmers executing the flutter kick had significantly less knee flexion than swimmers with slower speed. Ankle extension and ankle range in the flutter kick of women correlated positively and significantly with speed. Faster women exhibited significantly less knee flexion in the breaststroke kick than the slower swimmers.

Counsilman, J. E. (1948). A cinematographic and mechanical analysis of the butterfly breaststroke. Unpublished master's thesis, University of Illinois.

A systematic analysis of the butterfly breaststroke technique used in swimming by two former national champions was made.

Counsilman, J. E. (1955). Forces in swimming two types of crawl stroke . Research Quarterly, 26, (2), 127-139.

The resistive and propulsive forces of 3 swimmers using two types of crawl strokes - the glide stroke and the continuous stroke - were measured. These forces were measured with an apparatus utilizing strain gauges. Results indicated that the continuous stroke was faster than the glide stroke and created more propulsive force with less fluctuation in the application of the force.

Counsilman, J. E. (1980). The importance of hand speed and acceleration in swimming the crawl stroke. In J. M. Cooper & B. Haven (Eds.), Proceedings of the Biomechanics Symposium (pp. 226-238). Indiana University: Indiana State Board of Health.

The purpose of this study was to examine the hand speed patterns of world class swimmers to determine if there are similarities among them, and how they compare with those of poorer swimmers. Underwater strokes of three swimmers were filmed from two angles while swimming at about 80% effort and compared with poorer swimmers films. Poorer swimmers took longer to complete their underwater arm pull. As the arm is pulled through the water, the hand velocity, relative to the position of the body, increases significantly, achieving maximum speed when the arm pull is at 65 to 80% of completion.

Courtway, R. (1973). A comparison of three breaststroke turns. Swimming Technique, 10, 59-60.

This study compared 3 methods of executing the competitive breaststroke turn and their effects on swimming fifty yds. Twenty nine advanced and 30 novice breaststrokers were tested. Each of the three turns were tested over a distance of 50 yds. The subjects were instructed to practice the required turn for 15 min. each day. No significant differences in the total time required to swim 50 yds. by advance and novice breaststrokers when the AAU, NCAA, and somersault turns were used. Execution of a somersault turn by both groups was significantly slower than the execution of the AAU, and NCAA turns. Mean time for executing the NCAA turn was faster than the actual mean time for executing the AAU and the somersault turns. A significant relationship existed between the gliding time and the total time for 50 yd. when the NCAA turn was executed by the advanced breaststrokers. No significant relationship existed between the gliding time and the total time of 50 yd. when the AAU turn was executed by the advanced breaststrokers.

Cureton, T. K. (1930). Objective tests of swimming. Unpublished master's thesis, Springfield College.

This study tested difference in strength of different types of arm pull, the variance of which was determined by the degree of bend at the elbow. The swimmers were tested on a plinth on strengths of the various pulls which were recorded by a pully arrangement attached to a spring scale. It was found that the arm created the greatest pull as registered by dynamometer when the bend at the elbow was 45 degrees. The strength of the pull decreased in direct proportion to the increase in the deviation of the arm from directly in front of the shoulder.

Cureton, T. K. (1930). Mechanics and kinesiology of swimming the crawl flutter kick. Research Quarterly, 1, 87-121.

Attempts were made with small groups of subjects to find the best way to

to teach the crawl flutter kick. Testing of the wedge effect of kicking, determining angle of down and up kicks, studies of peculiar kicks, comparing propulsive forces of different kicks, correlations of ankle flexibility with speed is included. Also studied the amount of knee action, width of the kick and a test of back and abdominal strengths of a group of expert crawl swimmers as compared with average crawl swimmers showed the experts to be 32% superior in abdominal strength and 19.6% superior in back strength. Speed in flutter kicking was found to be directly propotional to strength of back and abdominal muscle groups.

Cureton, T. K. (1935). A test for endurance in speed swimming. Research Quarterly, 6, (2), 106-112.

An endurance and power-mechanics test has been outlined. Instruction is given for administation of the test. The reliability of the test has been determined as .90 for speed and .77 for endurance. Norms and percentile charts are given to rate any swimmer.

Czabanski, B., & Koszczye, T. (1979). Relationship between stroke asymmetry and speed of breaststroke swimming. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 148-152). Baltimore: University Park Press.

The purposes of this study were to verify the extent of asymmetry in the motion of the lower limbs in the breaststroke; to define sex differences if they exist; and to examine the relationship between asymmetry and swimming speed. Thirty female and 27 male swimmers had lower limbs asymmetry measured by cyclophotography. The study concluded that asymmetry in leg kick patterns is present in most breaststroke swimmers and that in general men are more asymmetrical, but this difference diminishes at the same speed and that a positive relationship exists between the leg kick asymmetry and speed.

Decker, J. (1971). Time distance analysis of backstroke starts. Swimming Technique, 8, 3-58.

A time and distance analysis was made between the conventional backstroke start and a standing type of backstroke start. Fifteen male high school swimmers were instructed on the two starts and then timed at the following distances using the 2 styles of starting: (1) start to the swimmers average distance attained using the conventional start, (2) start to the swimmers average distance attained using standard start, and (3) start to a point 20 yds. from the start. A statistical evaluation showed a highly significant difference in favor of the standing start in all but the 1st timing situation. The standing start therefore was not significantly faster until a minimal distance was covered at which point the difference in favor of the standing start becomes highly significant. An appreciably longer distance was also covered by using the standing type backstroke start, indicating a more efficient method of starting.

Dell, R. (1967). Time differential between traditional and stand-up starts in freestyle swimming for high school age boys. Unpublished master's thesis, Central Missouri State College.

Ten male swimmers were timed in two starting postions, and a significant mean difference was observed between the two positions.

Devries, H. A. (1959). A cinematographical analysis of the dolphin swimming stroke. Research Quarterly, 30, 413-42.

This study presents a method for the measurement of component velocities of one stroke cycle. The ratio of maximum to minimum component velocities is suggested as an index of stroke efficiency. In two outstanding dolphin butterfly stroke swimmers an attempt was made to identify factors of body mechanics which might contribute to the variance of velocities within the stroke cycle of these swimmers.

Disch, J. G., Hosler, W. W., & Bloom, J. A. (1979). Effects of weight, height, and reach on the performance of the conventional and grab starts in swimming. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 215-221). Baltimore: University Park Press.

The components measured were reaction time, movement time and flight time of 30 female college swimmers. Starts were videotaped and analyzed. It was concluded that the anthropometric measures of weight, height, and reach were related to reaction time and flight time. The grab start was significantly faster from the time of the gun until toe clearance.

East, D. J. (1970). Swimming: An analysis of stroke frequency, stroke length and performance. New Zealand Journal of Health, Physical Education and Recreation, 3, 16-27.

This study was to investigate the relationships between stroke frequency, stroke length and performance in competitive sprint swimming. The performances of all competitors in each 110 yd. event at the 1969 New Zealand swimming championships were photographed using motion picture cameras. From these films stroke frequencies and stroke lengths were computed for about 100 competitors. A significant linear relationship was found between stroke frequency and time in men's freestyle and between stroke length and time in men's backstroke, and in men's and women's butterfly events. Improvement in performance depended upon increasing stroke frequency in men's freestyle, increasing stroke length in men's backstroke and butterfly, and increasing both stroke frequency and stroke length in women's butterfly.

Elliott, G. M., & Sinclair, G. (1971). The influence of the block angle on swimming sprint starts. In L. Lewillie & J. P. Clarys (Eds.), First International Symposium on Biomechanics in Swimming, Proceedings (pp. 183-189). Brussels: Universite Libre de Bruxelles.

The purpose of this study was to determine the effects of three angles of the platform on the horizontal component of the starting velocity and on the time of the application of this force. Forty-two subjects had 378 starts analyzed. Results are tabled and conclusions are made that there is no value associated with starting blocks with any degree of angle at all.

Flynn, S. A. (1960). Comparative study of two styles of racing starts in swimming. Unpublished master's thesis, Macmurry College.

Geer, J. M. (1969). Comparison of two freestyle flip turns for short sprint competition. Unpublished master's thesis, Springfield College.

This study was to determine which of two crawl flip turns, the one arm flip turn or the two pull through flip turn, was the fastest for short sprint competition in 25 yd. short course pools. Five varsity swimmers were given 7 trials for each of the two turns. Each trial consisted of timing of three phases: the in-time, the out-time and the total time. The difference in time between the two methods of turns was not statistically significant. The in time for the one arm turn was significantly faster than the two arm pull through turn.

Gentile, A. (1966). Comparison of dry and wet body starts in swimming. Athletic Journal, 47, (1), 76-77.

Ten high school freshmen, 5 competitive swimmers, and 5 non-competitive swimmers were tested to compare the wet and dry body starts for the 50 yd. freestyle. By examination of mean times, the dry start was superior.

Gibson, G., & Holt, L. E. (1976). A cinema-computer analysis of selected starting techniques. Swimming Technique, 13, (3), 75-79.

The purpose of this study was to determine which of three selected starting techniques was most effective. Results showed no significant differences between the dives of 11 swimmers.

Goldfuss, A. J. (1970). A temporal and force analysis of the crawl arm stroke during tethered swimming. Unpublished master's thesis, Pennsylvania State University.

An investigation to measure the time taken to execute selected phases of movement of the crawl stroke and quantify changes occuring during each phase over a 2 min., all-out, tethered performance. Maximum force and its point of occurance in the stroke cycle was determined by cinematography of 2 varsity swimmers. The phases included entry, pull, pull to push, push, and recovery.

It was found that the execution of a stroke cycle and each arm separately were characterized by increases in time over a 2 min. period, but the pattern varied for each swimmer. Most of the increase in time over a 2 min. period for the left arm stroke occured underwater. Little or no change in time was found during the recovery phase. The most consistent increase in time occured during the entry phase for the left arm stroke by both swimmers. Coordination and timing of the arm remained fairly constant throughout each performance. The magnitude of maximum force decreased for each arm during each performance but the pattern varied. Arm strokes on the breathing side produced greater maximum force than the arm strokes on the non-breathing side. For both subjects the left arm produced the greatest force. It was concluded that the time taken to complete an arm stroke cycle increased and the magnitude of force decreased with time.

Goldfuss, A. J., & Nelson, R. C. (1971). A temporal and force analysis of the crawl arm stroke during tethered swimming. In L. Lewillie & C. P. Clarys (Eds.), First International Symposium on Biomechanics in Swimming, Proceedings (pp. 129-141). Brussels: Universite Libre de Bruxelles.

A synopsis of master's thesis, Pennsylvania State University, by Goldfuss, A. J., (1970).

Grimston, S. K., & Hay, J. G. (1984). The relationship among anthropometric and stroking characteristics of male varsity swimmers. Medicine and Science in Sports and Exercise, Abstracts, 16, (2), 159.

A theoretical model was developed to identify anthropometric parameters relevant to success in swimming. Profile, cross-sectional and lengths of body segments were measured on 8 varsity swimmers using a photographic procedure. Motion pictures were taken of subjects competing in freestyle events over two swimming seasons and then analyzed to determine stroke length, stroke frequency, and stroke speed in each event. Results suggest that although stroke speed is little influenced by the physique of the swimmer, the combination of stroke length and stroke frequency used to attain a given stroke speed is very much a function of his physique.

Gross, E. A., & Thompson, H. L. (1957). Relationship of dynamic balance to speed and to ability in swimming. Research Quarterly, 28, (4), 342-346.

The 78 subjects of this study were advanced swimmers. Each was taught 9 swimming strokes and conditioned for 6 wks. The subjects were then tested for 30 yd. sprints and given the Bass test of dynamic balance. The findings indicated that individuals who have better dynamic balance can swim faster than individuals with poor dynamic balance. Individuals with better swimming ability, as determined by expert judgement, tend to have better dynamic balance than individuals with poor swimming ability.

Groves, R. (1971). A cinematographic analysis of four styles of racing start in swimming. Unpublished doctoral dissertation, University of Missouri.

Groves, R., & Roberts, J. A. (1972). A furthur investigation of the optimum angle of projection for the racing start in swimming. Research Quarterly, 43, (2), 167-174.

This study was to identify the optimum angle of projection for the racing start in swimming. Sixteen male college varsity swimmers were filmed against a grid while performing 5 trials of the racing start. Time and distance measurements were derived from the speed of the camera and from the grid. The optimum angle of projection was identified as 13 degrees downward from the horizontal. A common optimum angle existed for all subjects in the study. Minor deviations from this optimum angle did not produce deleterious results.

Guimaraes, A. C. S. (1982). A mechanical analysis of the grab starting technique in swimming. Unpublished master's thesis, University of Iowa.

Hairabedian, A. (1965). Kinetic resistance factors related to body positions in swimming. Unpublished doctoral dissertation, Stanford University.

The purpose of this study was to analyze the degree of water-friction forces exerted on the body as it assumes selected positions while being towed through the water by a mechanical divice. The following were considered. 1. The least resistant head position in the water. A) The water level just above the eyebrows. B) The head down with water level passing over the head. C) The chin up with water level passing under the chin. 2. Least resistant position for hands and arms when they are extended in the water. A) Hands apart shoulder width. B) Hands together palms down. Twenty subjects were towed about 65 ft. During which time a steady velocity was maintained. Water friction forces were measured. In every variable and all speeds but one, there were fewer water-fricition forces acting upon the body when the hands were together and the head down than in any other head and hand combination. An exception occurred at the slowest speed. While executing a turn and during the push off the wall after the turn, if the hands are together and the head is down, there should be a resultant increase in swimming speed.

Hairabedian, A. (1966). Kinetic resistance factors. Swimming Technique, 2, 105-106.

A synopsis of doctoral dissertation, Stanford University, Hairabedian, A. (1965).

Harris, A. J. (1952). An analysis of the straight-arm stroke and the bent-arm stroke in swimming the crawl. Unpublished master's thesis, State University Iowa.

Surplus propulsive force was determined for the straight-arm stroke and the bent-arm stroke on a swimmer over a range in velocity from zero to 4.44 ft. per sec. on the front crawl. The straight-arm stroke produced the greatest amount of surplus propulsive force at each velocity and tempo tested. With the bent-arm stroke it was possible to swim a faster tempo than with the straight-arm stroke. The bent-arm stroke at the "all out" tempo produced the greatest number of pounds of surplus propulsive force.

Harris, W. D. (1974). Comparative times required to complete various back stroke turns. Unpublished master's thesis, Springfield College.

This study was designed to compare the pivot, back and forward flip turns for competitive backstroke swimming to determine if differences between the turns exist. Sixteen college swimmers were tested. Time for the forward flip turn was faster than either of the others, however no significant differences were seen in the backstroke turns.

Havriluk, R. P. (1980). Optimal angle of entry for the grab start. In J. M. Cooper & B. Haven (Eds.), Proceedings of the Biomechanics Symposium (p. 324). Indiana University: Indiana State Board of Health.

The purpose of this study was to test the hypothesis that a curvilinear relationship exists in the grab start between angle of entry and horizontal underwater velocity of the center of gravity. Nine varsity swimmers were filmed in two trials of their usual grab start. It was concluded that a horizontal angle of projection would result in the best approximation of the optimal entry angle without a loss in horizontal projection velocity.

Havriluk, R. P., & Ward, T. (1979). A cinematographic analysis of three grab starts. Swimming Technique, 16, (2), 50-52.

This study was designed to explore the temporal and kinematic differences in the grab starts performed by 3 varsity swimmers with film at 100 frames per/sec. Some support is evident for the grab start.

Heusner, W. W. (1959). Theoretical specifications for the racing dive: Optimum angle of take-off. Research Quarterly, 30, 25-37.

This study is based on mechanical principles involved in the racing dive. A mathematical expression which described the time required to dive, was found to be very high for the 17 subjects tested. Optimum angles of take-off were determined for various personal characteristics and for specific conditions.

Higgs, S. L., & Gallagher, H. (1979). The effect of arm position on strength of pull in freestyle and backstroke. Swimming Technique, 16 (1), 24-27.

The purpose of this study was to compare strength of pull in six variations of the mid-stroke position in the front crawl and three variations of the mid-stroke in the backstroke. A sub-problem was to investigate strength differences between male and female age-group swimmers. Thirty swimmers (15 female and 15 male) were tested in the front crawl and backstroke positions. In the mid-stroke phase of the front crawl, strength is superior when pulling wide of the center line as compared to one on or beyond the mid-line. No differences were seen in the variations of the backstroke. There were no significant differences in pulling strength between male and female swimmers tested.

Hobbie, P. (1980). Analysis of the flat vs. the hole entry. Swimming Technique, 16, (4), 112-117.

The purpose of this study was to determine which of two entries was faster. Ten male college swimmers were tested. No significant differences were found between the two starts in the measures of time to water entry, underwater time, time to first stroke, and initial velocity of the center of gravity at take-off.

Holmer, I. (1979). Analysis of acceleration as a measure of swimming proficiency. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 118-124). Baltimore: University Park Press.

The purpose of this study was to develop a technique for reliable acceleration measurements and to analyze the data obtained for different swimmers and strokes. Acceleration was measured with a linear accelerometer. Three swimmers of differing abilities swam 1-2 min. at different velocities up to maximum. Intracycle acceleration analysis seems to provide a useful instrument for exploring swim stroke kinematics.

Hunt, R. R., (1976). A time comparison between the grab start and the track start in swimming. Unpublished master's thesis, West Virginia University.

Hungate, K. W. (1972). A study of three methods of initial arm movements used after a competitive backstroke turn. Unpublished master's thesis, East Carolina University.

This study was to analyze the initial arm movements used after a competitive backstroke turn. Methods used were the alternate-arm pull, the surrogate alternate-arm pull, and the double-arm pull. Eleven varsity swimmers were given 15 trials for each method after training on each. The double-arm method proved to be superior to either the surrogate alternate-arm pull or

alternate-arm pull.

Hurley, A. A. (1938). An investigation of the distribution of time in championship competitive swimming. Unpublished master's thesis, State University of Iowa.

This study was to establish standards for the distribution of time based on the performance of champions and near champions in swimming intercollegiate swimming events. Changes in velocity were gradual and not abrupt. A period of relatively fast swimming follows the start. This period is short and the swimming quite fast in the dashes. As the distance becomes longer, there is an increased duration of this period with relatively slower swimming. Velocity attained during the first 50 yds. is greater than that attained during any of the following units of the same race.

Irwin, L. W., & King, W. H., Jr. (1957). A time and motion study of competitive backstroke swimming turns. Research Quarterly, 28, (3), 257-268.

A time analysis and motion study of two methods of performing backstroke swimming turns: The universally accepted method with a two arm glide and the experimental method with a one arm glide. Significant time differences between the two turns were found for two groups of 50 subjects. The majority of swimmers achieved faster times using the experimental method. Utilizing underwater photography, motion studies determined that 7 distinct movements were eliminated when using the one arm push-off method.

Jensen, R, K., & Bellows, D. G. (1976). Upper extremity contraction moments and their relationship to swimming training. Journal of Biomechanics, 9, 219-225.

Upper extremity contration movement tests were carried out on 42 male swimmers. Half of the group underwent a period of swim training and it was found that the medium ability swimmers increased initial segments of the impulse and work output curves. Tests on the remaining swimmers showed that the higher ability swimmers had impulse and work output curves which were significantly greater than for the lower ability swimmers.

Jensen, R. K., & McIlwain, J. (1979). Modeling of lower extremity forces in the dolphin kick. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 137-147). Baltimore: University Park Press.

In this investigation empirical data were collected and used to estimate the segmental forces and moments of force in the dolphin kick. Two swimmers of international caliber, a female and a male were filmed from the side and below the surface. Anthropometric measurements taken of the lower extremity were used to formulate a geometric representation of the segments. Size and inertial parameters for the lower extremity segments of the two swimmers indicate the dimentions are similar, the the female having slightly greater mass in the foot

and less mass in the thigh and the male having a longer lower leg and foot.

Jorgensen, L. W. (1971). A cinematographic and descriptive comparison of three selected freestyle racing starts in competitive swimming. Unpublished doctoral dissertation, Louisiana State University and A & M College.

This study was to determine which of three competitive freestyle racing starts was the fastest among a group of 75 age group swimmers. The styles were the grab, the arms back, and the circular arm swing starts. A descriptive analysis and comparison of the three starts was also made on film from the best of the three starters in each group. There was no significant differences of speed among the three styles of racing start.

Karpovich, P. V. (1930). Swimming speed analyzed. Scientific American, 224-225.

The natograph, an apparatus devised to register the progress of swimmers by recording the time and distance covered enabled the experimenter to calculate the variations of speed in intervals as small as one fifth of a sec., and to measure the relative efficiency within a single cycle of a stroke. Records of a single swimmer on the breaststroke and the side stroke as well as the crawl and the backcrawl show the variation of speed during the strokes. variations of the speeds of these strokes were diagramed.

Karpovich, P. V. (1933). Water resistance in swimming. Research Quarterly, 4, 21-28.

Skin friction was found to be the most resistant factor in swimming. The type of suit was more important than the quality. There was an increase in resistance when a woolen suit was used, but no difference between silk suit and swimming nude. An exaggerated head lift creates increased resistance as does turning the head for breathing.

Karpovich, P. V. (1935). Analysis of the propelling force in the crawl stroke. Research Quarterly, 6, (2), 49-58.

The effectiveness of the arms and legs in the crawl stroke was studied. It was shown that the propelling force of the whole stroke was equal to the sum of the propelling forces developed by the arms and legs separately. A formula was developed and was suggested as a coach's aid with an explanation of its application. Good crawl swimmers derive 70% of their force from the arms and 30% from the legs.

Karpovich, P. V., & Pestrecov, K. (1930). Mechanical work and efficiency in swimming crawl and back stroke. Arbeitsphysiologie, 10, 504-514.

The problem of the mechanical work done in swimming crawl and back stroke

was studied. A mathematical analysis of the motion in the crawl stroke was undertaken and substantiated by a series of experiments. A dynamometrical estimation of the propelling force in various strokes was given. Formulas for the calculation of work in swimming crawl and back stroke were derived. A formula for the determination of the velocity with which the body enters water after a dive or a push-off start was given. Efficiency of swimming as a type of locomotion was estimated.

Kelly, J. F. (1973). An electrogoniometric and natographic analysis of the up and down phases of the dolphin butterfly kick. Unpublished master's thesis, Springfield College.

This study was to investigate differences between the contribution of the down phase of the dolphin butterfly kick to the propulsion of 5 varsity swimmers. Measures of linear velocity and angular velocity of the knee joint were made while they swam using the whole stroke and the kick only. There was no significant difference between the linear velocities attained. There was no difference between the contribution of the upkick and the down kick to the propulsive force of the swimmers in the dolphin butterfly stroke.

Kent, M. R., & Atha. J. (1971). Selected critical transient body positions in breaststroke and their influence upon water resistance. In L. Lewillie & J. P. Clarys (Eds.), International Symposium on Biomechanics in Swimming, Proceedings (pp.119-125). Brussels: Universite Libre de Bruxelles.

This study examines the assumption that their is a simple linear proportional increase in resistance with velocity to any given power and seeks to establish values for the resistance changes associated with selected and maintained, but normally transient, breast stroke body positioins. Three male swimmers were towed for 150 tests. In all five transient positions investigated resistance was directly propotional to the square of the velocity.

Kent, M. R., & Atha, J. (1973). Intra-cycle retarding force fluctuations in breast-stroke. Journal of Sports Medicine, 13, 274-280.

A knowledge of average water resistance of passive swimmers towed at constant speeds allows few predictions concerning the active stroke. In breaststroke where resistance is a major problem, frontal area and velocity are constantly changing. Tension was recorded continuously while towing 7 male and 6 female age group swimmers at a constant velocity. During each trial a single full power breaststroke was made and a family of tension variation curves for each subject allowed a study of intra-cycle resistance to be made. During the execution of the stroke, the retarding force was found to reach a peak which was about proportional to the square of towing speed.

Kersten, O. A. (1960). Propulsion factors in swimming the dolphin butterfly. Unpublished master's thesis, State University of Iowa.

The difference between the mean time for the dolphin kick with maximum knee action and minimum hip action was less than the mean time for the dolphin kick with maximum hip action and minimum knee action when the kick alone was used and when the kick was combined with the arm stroke.

King, W. M. (1956). Time and motion study of competitive back-stroke Swimming turns. Unpublished doctoral dissertation, Boston University.

This study was to determine which of two methods of backstroke turns was faster and more efficient. The standard back somersault turn followed by a two-arm glide was compared to an experimental turn followed by a one-arm glide on 50 college swimmers and 50 high school swimmers. They were instructed and timed on both methods. The experimental method of turning was faster than the standard method. Underwater photography and comparative motion analysis was also made. Increased efficiency in using the experimental method was attributed to the elimination of 7 distinct body movements from using the standard method.

Krahenbuhl, G. S., Plummer, R. F., & Gaintner, G. L. (1975). Motor and sensory set effects of grab-start times of champion female swimmers. Research Quarterly, 46, (4), 441-446.

Fourteen members of the 1974 women's national championship swimming team performed the grab-start under an enforced motor set and an enforced sensory set. Data supported the prediction that enforced motor set results in longer reaction, movement, and response times than does enforced sensory set.

Kruchoski, E. P. (1954). A performance analysis of drag and propulsion in swimming three selected forms of the back crawl stroke. Unpublished doctoral dissertation, State University of Iowa.

This study was to investigate the effectiveness of three selected forms of the back crawl stroke by means of a method of performance analysis. Three depths of arm stroke were investigated - a shallow-depth arm stroke, a medium-depth arm stroke, and a deep arm stroke. Drag was measured while towing the subjects in their normal swimming position on the back. The surplus propulsive force exerted by subjects swimming the backstroke was measured by means of a towing and releasing apparatus which controlled the velocities of the swimmers. A bow wave was observed which increased with velocity and was an important factor limiting speed in swimming. At each velocity the mean for the medium depth arm stroke was greater than the means for the other strokes measured. The mean velocity for the shallow-depth arm stroke was greater than the mean for deep arm stroke. The leg kick appeared to be an important factor in maintaining speed in swimming.

Larue, R. J. (1983). A biomechanical comparison of the grab start and the track start in competitive swimming. AAHPERD, Abstracts of Research Papers, 1, 20.

The purpose of this study was to analyze and compare the differences in reaction time, movement time, response time, flight time, completion time, horizontal impulse, horizontal force and attained velocity as measured through a biomechanical analysis of the grab start and the track start in competitive swimming. Eighteen swimmers were filmed and timed performing both starts. The flight time and completion time means were significantly faster for the track start. The other variables were not significantly different.

Larue, R. J. (1985). Future start. Swimming Technique, 21, (4), 30-32.

In this study, the grab start and track start were biomechically compared to determine any significant differences in reaction time, movement time response time, flight time, completion time, horizontal impulse, horizontal force or attained horizontal velocity. Eighteen subjects were filmed and then analyzed and from the results of the study it was inferred that the track start was faster than the grab start.

Lewis, S. (1980). Comparison of five swimming starting techniques. Swimming Technique, 16, (4), 124-128.

Five starting techniques were compared to determine which method was fastest in allowing a swimmer to reach a distance of 8M. from the block. Ten untrained male college students were taught to perform the five starts by five different teachers. Forty-two trials of each start were filmed. Analysis showed no significant difference in the time for swimmers heads to reach the 8M. distance.

Lockhart, S. (1966). A cinematographic analysis of the backcrawl stroke. New Zealand Journal of Physical Education, 38.

Lopin, V. (1947). A diagnostic test for speed in swimming the crawl stroke. Unpublished master's thesis, State University of Iowa.

This study was to devise a test for predicting speed in swimming the crawl stroke by measuring the resistance in water and the propulsive force of 31 swimmers. The propulsive force and weight correlated high with time.

Lowell, J. C. (1975). Analysis of the grab start and the conventional start. Swimming Technique, 12, (3), 66-69.

Twenty AAU swimmers were filmed to compare the grab start and the conventional start. Results indicated that the grab start was faster than the conventional start in time off the blocks. It was also faster in time of flight and out 20 ft. from the blocks, but no difference with regard to angle of flight.

MacDonald, F. W., Jr., & Stearns, W. J. (1969). A mathematical analysis of swimming the breaststroke and dolphin butterfly strokes. Unpublished master's thesis, Springfield College.

It was the purpose of this study to apply the Pythagorean theorem to the breaststroke and the dolphin butterfly stroke to determine the contribution of arms and legs in performing these strokes. Nineteen varsity swimmers swam the breaststroke for a total of 32 trials and 21 swam the dolphin for a total of 40 trials for 60 ft. at a maximum speed using arms alone, legs alone, and then whole stroke. In the breaststroke the arms contributed 53.5% to the whole stroke, while the legs contributed 46.5% in the dolphin butterfly the arms contributed 62.9% to the whole stroke while the legs contributed 37.1%.

Magel, J. R. (1970). Propelling force measured during tethered swimming in the four competitive swimming styles. Research Quarterly, 41, 68-74.

Force exerted during a 3 min. tethered swim was measured electrically by use of a force transducer in 26 trained college swimmers in each of the four competitive strokes. The swimmers were attached to a pulley and counterweight system by means of a restraining line attached to a belt worn around the waist. A force transducer was placed in the line. The test consisted of 3 min. swims with a 3-5 min. rest between each work level. The work load was increased each swim until the swimmer could not support the counterweight. Breaststroke swimmers recorded the highest average values for force exerted. Average propelling force recorded for back, front, and fly tethered swimming did not appear to differ. In fly swimming, the propelling forces delivered by arms and legs appear to be about the same.

Maglischo, C. W. & Maglischo, E. (1968). Comparison of three racing starts used in competitive swimming. Research Quarterly, 39, (3), 604-609.

Ten varsity swimmers were tested for speed doing each of three starts: Straight-backswing, circular-backswing, and arms-back. Each swimmer did 30 legal starts, 10 of each type. Results indicated that the circular-backswing start was significantly faster than the straight-backswing start, but no difference was found between the arms-back and the circular-backswing or the arms-back and the straight-backswing starts.

Maglischo, E. W., Maglischo, C. W., Zier, D. J., & Santos, T. R. (1985). The effect of sprint-assisted and sprint-resisted swimming on stroke mechanics. Journal of Swimming Research, 1, (2), 27-33.

Four male and 2 female competitive swimmers, ages 13 to 17, were filmed sprinting butterfly. They swam about 40 ft. under three conditions: Untethered, partially-tethered by a swim belt, and using the swim belt as a means of sprint-assisted training. Films were digitized and coordinates analyzed by computer. Subjects required less time to complete underwater

armstrokes during sprint-assisted trials and more time during the sprint-resisted trials. Subjects' hands followed different paths during the 3 trials. They exhibited differing degrees of maximal elbow flexion at mid-stroke, but there was no consistent direction to these differences. Most of the swimmers flexed their wrists more at mid-stroke during both sprint-assisted and sprint-resisted trials and hyperextended their wrists more during sprint-assisted trials. They tended to hyperextend their wrists less during sprint-resisted trials.

Mathews, M. P. (1954). Role of the arm and leg factors in the total propelling force in swimming. Unpublished master's thesis, University of California.

Mc Cutchan, T. W., Jr. (1973). A cinematographical analysis of the grab start in comparison to the conventional start in competitive swimming. Unpublished master's thesis, Springfield College.

This study was designed to measure and compare two methods of starting for competitive swimmers at college and high school age levels. Three trials at each of the 2 starts were filmed and analyzed for each of 20 subjects. The grab start was found to be faster than the conventional start from the flash of the gun to a distance of 23 ft. College age subjects had faster times than high school age subjects in both starts.

McEvoy, J. E. (1975). Analysis of the individual medley swimming test. Unpublished doctoral dissertation, Springfield College.

Michaels, R. A. (1968). The roll backstroke turn. Swimming Technique, 5, 70-72.

One subject over a period of 5 days did 100 turns - 50 conventional turns and 50 roll turns from the backstroke. Flip and roll turns were done alternately so as to minimize the swimmer fatigue factor. The same swimmer and timer were used each day so the skill improvement for timer and swimmer were held constant. Time was recorded from hand touch until feet broke contact with the wall so as to minimize the variance in entrance and exit speeds of the swimmer. The roll turn averaged about .2 sec. faster in a race with three turns.

Michaels, R. A. (1973). A time distance comparison of the conventional and grab start. Swimming Technique, 10, 16-17.

Six varsity swimmers were given five grab and conventional start trials with half of the subjects starting with the conventional start trial first, and the other half beginning with the grab start. Of 6 participants who had no prior experience with the grab start, 4 had faster average times

for the grab start trials. No statistical analysis was shown.

Michaels, R. A. (1974). Is the underwater pushoff faster? Swimming Technique, 11, (1), 12.

Six varsity swimmers did pushoffs from pool end and were timed on both underwater and surface pushoffs for six yds. The underwater pushoff was faster for all subjects. The average was .127 secs. faster.

Miller, D. I. (1975). Biomechanics of swimming. In J. H. Wilmore & J. F. Keogh (Eds.), Exercise and Sport Sciences Reviews (pp. 219-248). New York: Academic Press.

Not an experimental study, but an excellent review of swimming from a biomechanical standpoint. It begins on a desciptive level and identifies the status of human propulsive efforts in terms of velocity, relevant forces and mathematical models of the system, and the link between the biomechanical and physiological bases of performance.

Mindheim, A. D. (1960). Speed and propulsive force of two types of back-crawl stroke. Unpublished master's thesis, State University of Iowa.

This study was to determine the relative effectiveness of the bent-arm and straight-arm strokes in swimming the backstroke for a distance of 30 yds. on ten varsity swimmers. No statistically significant differences were found.

Miyashita, M. (1974). Method of calculating mechanical power in swimming the breaststroke. Research Quarterly, 45, (2), 128-137.

Work output in swimming the breaststroke was estimated by means of a derived formula and photography. Four different subjects swam 25M. all out and their movements were filmed by high speed camera. Progressive speed was analyzed. Trained swimmers were superior in speed to untrained. Stroke cycle periods were shorter for the trained than the untrained. The mechanical work output was estimated. High power was produced during the kick phase, but after kicking is completed no work is done for a short period by the trained and for a longer period by the untrained. High power is produced by the trained and low power by the untrained during the pulling phase. Minus power was produced during the recovery phase by all subjects.

Mosterd, W. L., & Jongbloed, J. (1964). Analysis of the stroke of highly trained swimmers. Arbeitsphysiology, 20, 288-293.

Propelling forces were recorded on 30 swimmers, swimming on the spot in various styles. Obtained graphs were analyzed. The highest values of the propelling force were found in the orthodox breaststroke.

Nicol, K., & Kruger, F. (1979). Impulses exerted in performing several kinds of swimming turns. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 222-232). Baltimore: University Park Press.

The purpose of this study was to provide biomechanical descriptions and analyses of the flip turn and the open turn used in freestyle swimming. Four female and 1 male college swimmers were measured in several parameters while completing these turns. The flip turn showed some advantage over the open turn.

Oaks, H. D. (1936). A study of the optimum time for holding a swimmer on his marks. Unpublished master's thesis, State University of Iowa.

Data collected from 10 varsity swimmers to discover the relation between the length of time which they were held on their mark, and the time which they consumed in executing their start, showed no significant difference between starting time and holding time. The optimum holding time for the swimming start was found to be .2 seconds.

Osborn, L. L. (1941). A method of analysis of swimming strokes with relation to the application of force. Unpublished master's thesis, University of California at Los Angeles.

This study involves the use of motion picture films for photographing two swimmers under water in slow motion to determine speed and acceleration curves for each arm cycle. It furnished a method of attack upon problems in swimming such as the optimum length of lever, plane of pull, and the relation between the form of the stroke and speed. Curves are given for each subject.

Over, M. E. (1964). A comparison of the force and resistance of the frog kick and whip kick used in swimming the orthodox breast stroke. Unpublished master's thesis, Long Beach State College.

This study was to compare the breaststroke frog kick and whip kick, in terms of the force and resistance factors which relate to the speed and efficiency of the stroke. One subject was given 13 propulsive force trials for both kicks. Twelve kick resistance measurements were made while the swimmer was being towed. When speeds were comparable, more whip kicks were used to go a given distance than frog kicks. The frog kick was more powerful than the whip kick when executed with resistance.

Pai, Y. C., Hay, J. G., Wilson, B. D., & Thayer, A. L. (1984). Stroking techniques of elite swimmers. Medicine and Science in Sports and Exercise, Abstracts, 16, (2), 159.

The purposes of this study were to determine the average stroke length (SL), average stroke frequency (SF), and average speed (S) of elite swimmers in the four competitive strokes. Then to compare results for the parameters. The S and Sl of the males were significantly higher

than the females. Strong negative correlations were found between SL and SF. None were found between S and either SL or SF. These results suggest that well trained swimmers achieve very similar S with very different combinations of SL and SF.

Pelchat, C. (1971). A biomechanical analysis of selected racing starts in swimming. Unpublished master's thesis, Pennsylvania State University.

The purpose of this study was to investigate and compare through cinematography the biomechanics of the freestyle and breaststroke starts. Ten varsity swimmers performed 5 freestyle starts and 5 breaststroke starts. No differences in the mechanics of the starts was found except for the angle of body position at water entry.

Persyn, U., Demaeyer, J., & Vervoeche, H. (1975). Investigation of hydrodynamic determinants of competitive swimming strokes. In J. P. Clarys & L. Lewillie (Eds.), Swimming II. International Series on Sports Sciences (pp. 214-222). Baltimore: University Park Press.

Not an experimental study, but a film analysis for comparison of stroke mechanics.

Plummer, C. R. (1940). Cyclic velocity variations of the breast and butterfly strokes. Unpublished master's thesis, Springfield College.

This study was to measure the velocity variations that occured within a single cycle of the breast and butterfly strokes. Six competitive swimmers were tested with the natograph. For good swimmers the breaststroke was a slower stroke than the butterfly, but with poor swimmers there was very little difference between the average velocities developed with the two strokes. Using arms alone, the butterfly was faster than the breaststroke.

Poulos, G. L. (1949). An analysis of the propulsive factors in the American crawl stroke. Unpublished master's thesis, State University of Iowa.

This study analyzed the propulsion of 2 types of arm action on 25 swimmers and studied the different types of leg action as they related to the propulsion of the whole stroke. Three types of leg action, narrow, normal and wide were used. The speed of swimming was greater with the narrow kick than with either the normal or wide kick. The average time was shorter with the long arm stroke than with the short arm stroke.

Pulley, F. C. (1955). Relationship of speed swimming and buoyancy to form in the execution of the front crawl stroke. Unpublished master's thesis, Smith College.

The purpose of this investigation was to determine the relation of speed swimming with the front crawl stroke and bouyancy to form in the execution

of the front crawl stroke. Subjects were a group of 112 females of high school and college age. A subjective rating on form was given by 3 judges on the front crawl stroke. Time was taken to swim 25 yds. Bouyancy was determined subjectively by position assumed on the float. There was a significant positive relationship between form in swimming the front crawl and speed in the same stroke. The low negative relationship between speed in swimming the front crawl and bouyancy indicated a tendency for the faster swimmers to be poorer floaters. There was a negligible relationship between form in swimming the front crawl and bouyancy. Bouyancy can be expected to have no influence on ability to perform the front crawl in good form.

Ransom, G. G. (1973). The no breather flip turn. Swimming Technique, 10, 70-82.

This study tested the amount of resistance between breathing before and after a turn as compared with holding the breath for one full stroke before the turn and off the wall. Eighteen swimmers were timed on five trials over a six week period. All 18 swimmers had fastest turns recorded on the no breather step. Any breathing done immediately before and/or after the turn causes loss of speed and a slower turn. If a need to breath was felt, then the breath after the turn would be better than before the turn.

Reischle, K. (1978). Lightstreak photography: A simple method for recording movement patterns. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 408-414). Baltimore: University Park Press.

The principle purpose of this study was to conduct an objective analysis of movement skills with the aid of a lightstreak method. An attempt was made to analyze the typical level of motor skill in swimming and to record directly the momentary effective stroke length for swimming the crawl, backstroke, and butterfly. Analysis of the light rays gave significant information about propulsion during swimming of 30 physical education students and 40 highly skilled swimmers and provided information on the influence of training methods on movement patterns, success or failure as the result of different teaching methods, e.g., part-whole versus whole method, and consequences of peripheral and central fatigue on swimming technique compared with physiological parameters.

Reischle, K. (1979). A kinematic investigation of movement patterns in swimming with photo-optical methods. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 127-136). Baltimore: University Park Press.

The purpose of this study was to find kinematic parameters that determine the performance of the swimmer, and support quantitatively the biomechanical model of an optimal movement pattern in swimming. Sixty highly skilled age-group swimmers (36 females and 24 males) and 44 untrained students were tested with lightstreak photography and compared. Results are tabled and significant differences described in both females and males.

Ringer, L. B. (1966). An electrogoniometric study of the wrist and elbow in the crawl arm stroke. Unpublished doctoral dissertation, Springfield College.

See Ringer, L. B. & Adrian, M. J. (1969) for annotation.

Ringer, L. b., & Adrian, M. J. (1969). An electrogoniometric study of the wrist and elbow in the crawl arm stroke. Research Quarterly, 40, (2), 353-363.

The purpose of this study was to investigate the flexion and extension patterns of the wrist and elbow joints of 18 varsity and untrained swimmers during the sprint crawl stroke. Each sprinted the crawl stroke, from a dead start 4 times over 20 yds. The wrist and elbow actions were recorded by means of waterproofed electrogoniometers. Varsity groups showed greater extension of the elbow at entry, greater extension of the elbow in the first part of the underwater portion of the stroke, greater extension of the elbow at exit, and greater angular velocity of elbow flexion and extension. Duration of the underwater portion of the stroke for the better varsity group was the longest and their mean swimming speed was the fastest of the three groups.

Roffer, B. J. (1971). A comparison of the grab and conventional racing starts in swimming. Unpublished master's thesis, Pennsylvania State University.

This study was to compare the conventional racing start with the grab start in terms of the times required for each starting technique. Nine varsity swimmers were given 10 starts, 5 of each starting technique and filmed at a speed of 100 frames per sec. The starting, flight and total times were determined by counting the number of light markings on the film for each of ten trials. The grab start was significantly faster than the conventional start in starting time. There was no difference between the flight times for either start. The total time for the grab start was significantly less than the total time to execute the conventional start. It was concluded that the grab start was superior to the conventional start.

Roffer, B. J. (1972). The grab start is faster. Swimming Technique, 8, 101-102.

A film analysis and comparison of times from 9 varsity swimmers starting in the grab and conventional arm swinging styles shows the grab start was faster over a 12 foot distance measured from the starting block. The mean time advantage of the 9 subjects on the grab start was a tenth of a second.

Roy, W. D. (1938). A study of the factors influencing the start of the swimming sprint. Unpublished master's thesis, State University of Iowa.

This study was a comparison of holding times with starting times of 15

trained and 5 untrained swimmers. A holding time of 1.5 sec. gave a faster starting time for trained swimmers than either 1.0 or 2.0 sec. It took a trained swimmer .95 sec. to leave his mark at the start of a race.

Sanders, C. L. (1968). A photographic analysis of five methods of free-style swimming. Unpublished master's thesis, North Carolina College at Durham.

The purpose of this study was to determine the number of movements in each of the five methods of freestyle swimming, and to present detailed photographic illustrations of these strokes. It was found that mastery of various movements in each stroke is essential for getting maximum amount of propulsion and the minimum amount of resistance from each movement. Strokes having more propulsion with less resistance to the water were faster than strokes with more resistance and less propulsion to the water. The American crawl had less resistance to the water than any of the other strokes.

Scharf, R. J., & King, W. H. (1964). Time and motion analysis of competitive freestyle swimming turns. Research Quarterly, 35, 37-44.

A group of 47 swimmers were initially instructed and timed on the modified flip turn followed by a two-arm glide, which was the universally accepted method. The subjects then were instructed and timed in the new experimental turn, which is similar to the modified turn, but followed by a one-arm glide. Results indicated the experimental turn was faster than the modified method. Through subjective analysis, four movements found in the modified turn were eliminated by using the experimental turn followed by the one-arm glide.

Scheuchenzuber, H. J., Jr. (1970). A biomechanical analysis of four backstroke starts. Unpublished master's thesis, Pennsylvania State University.

The purpose of this study was to investigate the differences in speed and mechanical factors of 4 competitive backstroke starts. Measurements were obtained cinematographically. Ten subjects were given a pre-practice test of 40 starts, four one-half hour practice sessions and a post test on all four starts. Filming done at the post test showed that the starting method using the AAU and FINA prescribed foot placement was significantly slower than that prescribed by the NCAA of allowing the toes over the edge of the gutter.

Scheuchenzuber, H. J., Jr. (1974). Kinetic and kinematic characteristics of tethered and non-tethered swimming of the front crawl arm stroke. Unpublished doctoral dissertation, Indiana University.

Schiessel, M. L. (1966). An analysis of competitive freestyle swimming turns. Unpublished master's thesis, University of California, Santa Barbara.

Schleihauf, R. E., Jr. (1979). A hydrodynamic analysis of swimming propulsion. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 70-109). Baltimore: University Park Press.

A two part study, the first investigated the lift or drag of hand models and the second part analyzed motion pictures of highly skilled swimmers in their propulsive techniques. In summary it seems that effective technique in freestyle can be generated for a broad range of swimming styles.

Scott, S. (1969). Factors influencing whip kick performance. Unpublished master's thesis, Washington State University.

None of six anatomical measures examined was successful in predicting whip kick performance in women swimmers.

Shea, J. (1970). A cinematographic study of two methods of performing the propulsive hand-arm phase of the butterfly stroke. Unpublished master's thesis, Springfield College.

The straight line method of force application was found to be more effective than the s-curve pull method. Some reservations were indicated.

Shierman, G. (1977). The grab and conventional starts in competitive swimming. Proceedings SAAHPER Research Council, Atlanta.

Shierman, G. (1978). Stability in competitive swimming starts. Swimming Technique, 14, (4), 117-118.

Six male and 5 female varsity swimmers performed starts from a force platform using both conventional and grab starts. Tracings are shown. The grab start was a more stable position. Women tend to be more stable then men.

Stevenson, J. R. (1977). The influence of starting block angle on the grab start in competitive swimming. Unpublished master's thesis, Pennsylvania State University.

See Stevenson, J. R., & Morehouse, C. A. (1979) for annotation.

Stevenson, J. R., & Morehouse, C. A. (1979). Influence of starting-block angle on the grab start in competitive swimming. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 207-214). Baltimore: University Park Press.

The purpose of this study was to determine, through the use of cinematography and a strain-guaged starting block, the effects of starting block angles of 0, 10, 20 and 30 degrees above the horizontal on a 25 yd. swimming performance using the grab start. Ten male college swimmers were filmed and analyzed on the grab start. The performance of the start and subsequent swim is effected by a change in starting block angle above the horizontal. The 20 degree angle provided the most advantages in reducing the time required for the performance of the grab start and swim.

Straub, E. J. (1951). A photographic analysis of seven turns used in competitive swimming. Unpublished master's thesis, University of North Carolina.

The purpose of this study was to illustrate and analyze the mechanics of 7 selected turns used in competitive swimming. Rapid sequence photographs were taken by means of an underwater photographic technique. Sequential photographs were taken of the crawl spin turn, the crawl flip turn, the crawl distance turn the crawl back flip turn, the back stroke spin turn, the back stroke flip turn and the breast stroke turn. Some common faults are noted.

Tendy, S. M. (1974). A biomechanical analysis of the freestyle arm stroke. Unpublished master's thesis, Pennsylvania State University.

Thrall, W. R. (1960). A performance analysis of the propulsive force of the flutter kick. Unpublished doctoral dissertation, State University of Iowa.

Results indicated that at a stroke frequency of one arm stroke cycle/sec. the action of the legs in the sprint crawl stroke should involve six beats.

Tilley, J. L. (1951). The relation of land drills and other tests to speed in swimming. Unpublished master's thesis, University of Illinois.

This study was to investigate the relationship of land drills to speed in swimming and to investigate the relationship between speed in swimming and 27 other tests. Two land drills, the back flutter kick and the front flutter kick were significantly correlated with a 20 yd. sprint. Little relationship was found between land exercises and speed in swimming.

Vaday, M., & Nemessuri, M. (1971). Motor pattern of free-style swimming. In L. Lewillie & J. P. Clarys (Eds.), First International Symposium on Biomechanics in Swimming, Proceedings (pp. 167-173). Brussels: Universite Libre de Bruxelles.

The purpose of this study was to determine the main forces that give propulsion to the free-style crawl. Fourteen swimmers were filmed

from underwater and the movements analyzed. A motor pattern was noted, action of the main joints examined, and the important muscles which took part in the main movements were delineated.

Valett, H. B. (1948). An experimental study of the back stroke start in swimming. Unpublished master's thesis, State University of Iowa.

Starting times of 25 experienced backstroke swimmers employing the aid of a foot-hand support unit, and also without the unit were recorded. Each one had 8 starts with and without supports. Starting times from the supports were 0.12 sec. faster than starts without supports. Hands placed on a hand rail 20 inches above water gained over a position where hands were closer to the feet. There was a significant advantage of a stride position on the foot support over that of feet placed on the flat vertical wall in the same position.

Van Slooten, P. H. (1973). An analysis of two forward swim starts using cinematography. Swimming Technique, 10, 85-88.

The purpose of this study was to compare two forward swimming starts, the traditional windup start and the grab start. The comparison was done in terms of acceleration, velocity, displacement, angle of take off, and theoretical path of the body's center of gravity. A 16 mm film was taken of the subject during three trials for each start. The grab start produced the greater velocity, faster take-off, and faster time to the water. The traditional start produced a greater angle of take-off, greater acceleration, and a greater distance into the water.

Vaudry, S. (1976). A comparison of breast stroke and back crawl in men and women. Unpublished master's thesis, State University of New York at Buffalo.

Ward, T. A. (1976). A cinematographical comparison of two turns. Swimming Technique, 13, (1), 4-6.

The purpose of this study was to determine which freestyle flip turn, the pike or tuck, is faster for competitive swimming. Fourteen college students were matched and instructed in the turns and filmed during performance. The tuck turn was found to be significantly faster.

Warner, D. E. (1940). A cinematographic analysis of swimming strokes. Unpublished master's thesis, Springfield College.

The purpose of this study was to show by transcription of underwater cinematographic pictures the stroke sequence of the four competitive swimming strokes. It is not a study of the mechanics of the strokes, but a descriptive study of the strokes.

Waterfield, D. A., Jr. (1964). Effects of hand-foot placement on reaction and performance times in the backstroke start. Unpublished master's thesis, Springfield College.

This study was to determine the effect of hand-foot placement on reaction and performance time of backstroke starts. Nineteen male swimmers were tested for nine backstroke starts at each of three starting heights. The reaction and movement times were combined to yield performance times. The 18 in. starting bar yielded reaction times that were significantly faster than the other two heights. It also yielded the fastest performance time, but this was not significant.

Watkins, J., & Gordon, A. T. (1982). The effects of the leg action on performance in the sprint front crawl stroke. The V International Congress on Biomechanics and Medicine in Swimming.

The effects of flutter kick on freestyle sprint swimming performance were measured in a group of 36 highly skilled swimmers through the use of kinematic analysis. Freestyle kick was found to contribute indirectly to propulsion in two ways: first through stabilization of the trunk (accounting for about 9% of the full-stroke speed); second, by streamlining the body (accounting for about 11% to 6% for full stroke speed in males and females respectively).

Welch, J. H. (1974). A kinematic analysis of world class crawl stroke swimmers. Unpublished doctoral dissertation, Springfield College.

This study was to describe and analyze by kinematic techniques, selected movements of the trunk and upper extremity as displayed by 10 world class crawl stroke swimmers engaged in competition. There were no major differences in patterns of motion on the breathing and non-breathing sides.

Winters, C. N. (1968). A comparison of the grip start and the conventional start in competitive swimming. Unpublished master's thesis, Southeast Missouri State College.

Five college male varsity swimmers were analyzed through cinematography. Grip start was found to be significantly better than the conventional start on the time it takes to leave the blocks, the time it takes to enter the water, and the velocity of the swimmer upon entry into the water.

Wood, T. (1977). A fluid dynamic analysis of the propulsive potential of the hand and forearm in swimming. Unpublished master's thesis, Dalhousie University.

See Wood, T., (1979) for annotation.

Wood, T. A fluid dynamic analysis of the propulsive potential of the hand

and forearm in swimming. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 62-69). Baltimore: University Park Press.

This study was designed to examine the fluid foil characteristics of the hand and forearm in model form, in a controlled and measurable situation, to determine the nature and magnitude of the forces that the upper limb can generate. The problem was investigated by studying the behavior of hand and forearm models under conditions of air flow in a wind tunnel. Both lift and drag forces play a part in swimming propulsion.

Yeater, R., Martin, R. B., White, M. K., & Gilson, K. (1981). Tethered swimming forces in the crawl, breast and back strokes and their relationship to competitive performance. Journal of Biomechanics, 14, (8), 527-537.

Forces developed during fully tethered swimming by 18 male athletes were measured using a load cell in the tether cable. Three competitive strokes were studied: crawl, breast and back. Arm and leg components of the crawl and breast were observed separately. Attempts were made to correlate peak and mean tether forces with competitive velocities. A positive correlation was observed between mean tether force and velocity in the crawl, particularly among distance swimmers. A negative correlation was found between crawl velocity and peak/mean force ratio. The data suggest that the kick contributes significant force in both the crawl and breaststroke. In neither case, however, does the whole stroke produce as much force as the sum of the arm and leg components would indicate.

Zatsiorsky, V. M., Bulgakova, N. Z., & Chaplinsky, N. M. (1979). Biomechanical analysis of starting techniques in swimming. In J. Terauds & E. W. Bedingfield (Eds.), Swimming III (pp. 199-206). Baltimore: University Park Press.

The purpose of this study was to compare the efficiencies of four swimming start techniques and to identify the key factors that affect starting performance. Two experiments using 105 swimmers determined that swimming starts involving a full arm swing, forward arm swing, or grabbing the starting block are equally efficient, while the track start is less efficient.

Zeh, B. S. (1965). A comparison of the efficiency of four styles of breast stroke. Unpublished master's thesis, University of North Carolina.

Four different breaststroke styles were compared. A horizontal pull and wedge kick proved significantly more powerful than other combinations.

Psychological Aspects

Armbruster, D., Morehouse, L., & Tuttle, W. W. (1939). The optimum time for holding a swimmer on his mark. Research Quarterly, 10, 92-98.

Ten varsity swimmers were tested to find the relation between the length of time which they were held in the mark position and the time consumed in executing their start. The holding times studied were from 1.0 sec. to 2.2 secs. Results show that the optimum holding time was 2.0 sec. 1.8, 2.0, and 2.2 sec.

Armbruster, D., Morehouse, L. E., & Tuttle, W. W. (1940). A further study of the optimum time for holding a swimmer on his mark. Research Quarterly, 11, 53-56.

The data obtained from a comparison of holding times with starting times of 15 untrained swimmers warrant the following conclusions: a period of about 1.5 sec. is optimum for reaching the peak of attention during the start of a swimming race from a "set" position. A hold time of 1.5 sec. yields a faster starting time for trained swimmers than either 1.0 or 2.0 seconds in the majority of cases.

Bell, K. F. (1974). Effects of self-monitoring and graded practice in interval training performance in a competitive swimming environment. Unpublished doctoral dissertation, University of Texas at Austin.

This study explored the effects of an improved graded practice routine and self-monitoring of daily practice times on performance of a college swim team. Team members were assigned to one of four conditions. They were self monitoring and graded practice, graded practice alone, self-monitoring alone, or neither experimental condition. Self-monitoring and graded practice when used by themselves significantly enhanced the swimmers benefit from practice. Swimmers receiving both of these innovations showed only marginal improvement as compared with the group receiving neither procedure.

Bell, K. F., & Patterson, M. R. (1978). A self monitoring technique for enhancement of swimming performance. Swimming Technique, 14, (4), 103-106.

Experiment 1 in this study involved the use of publicly self-recording attendance to reduce absenteeism, late arrivals, and early departures from swimming practice. In experiment 2 large program boards were used to try to increase work output. It was felt that clear, accurate results were obtained from which standards were derived and a self reward system set up, thereby enhancing performance.

Brown, E. A. (1969). A comparative study of personality traits of varsity skiers, varsity wrestlers, varsity swimmers, and collegiate non-athletes at selected institutions of higher learning in the intermountain area. Unpublished doctoral dissertation, University of Utah.

This study was to determine differences in personality traits among select groups of varsity skiers, wrestlers, swimmers and collegiate non-athletes. The Edwards personal preference schedule was given to 300 subjects including 44 varsity skiers, 85 varsity wrestlers, 64 varsity swimmers and 107 collegiate non-athletes. The varsity swimming group scored significantly higher than the collegiate non-athletes when compared on the heterosexuality variable. No statistically significant differences were found among the other groups.

Buck, M. C. (1967). The effects of two practice techniques on selected swimming strokes. Unpublished doctoral dissertation, University of Iowa.

This study was to determine the effects of mental practice and land practice on learning the front crawl and breaststroke at the intermediate level of swimming skill. Eighty-five men and 47 women of intermediate level were tested on speed, power and form and taught under two practice techniques. All groups improved significantly. Mental practice and land practice did not cause any greater improvement than additional time in the water. Speed and form seemed more closely related than speed and power or form and power.

Campbell, W. A. (1974). The self concept of the black competitive swimmer: Psychocultural analysis, by Wilburn A. Campbell, Jr. Unpublished doctoral dissertation, Springfield College.

Cicciarella, C. F. (1983). The effectiveness of the crawl stroke and breaststroke sequence in teaching beginning swimming. AAHPERD, Research Abstracts, 1, 26.

The purpose of this study was to compare the effectiveness of two different sequences of skills used in teaching swimming to non-swimmers. A total of 131 non-swimmers were given instruction, where 68 were taught using an experimental technique and 63 were taught using the control sequence. The experimental sequence was statistically superior to the control sequence as measured by maximum swimming distance, maximum floating time, and time required to swim 50 yds.

Dyer, K. F. (1976). Social factors influencing female swimming performance. Journal of Biosocial Science, 8, 131-136.

The differences between male and female performance in freestyle swimming events are compared. It was found that the difference between these performances, as measured by world records, is declining in all events and most in events where the difference is largest. Analysis of national records show differences between countries in average male/female differentials.

A different set of physical and physiological constraints operate on swimming compared to track performance. Social factors seem to be less important in swimming than in track athletics in perpetuating performance

differences, but are nevertheless still operative.

Prager, S. R., & Spector, J. (1979). Hypnosis and behavioral techniques improve swimming performance. Swimming Technique, 16, (3), 77-81.

Psychological techniques were used to improve swimming performance in two AAU athletes. Background information and performance data on each swimmer are presented, and conclusions and possible applications are discussed.

Gaintner, G. L. (1977). What athletes and coaches expect of coaches. Swimming Technique, 14, (2), 45-48.

To determine important underlying aspects of the coach-athlete relationship, a survey of athletes' and coaches' expectations of coaches was completed. The group consisted of 73 water polo athletes, 50 swimmers, 14 water polo coaches and 10 swimming coaches. Differences were not apparent between the groups surveyed regarding their expectations.

Hendry, L. B. (1968). Assessment of personality traits in the coach-swimmer relationship, and a preliminary examination of the father-figure stereotype. Research Quarterly, 39, (3), 543-551.

Personality traits were assessed on the 16 PF questionaire (Cattell) of 126 swimmers and coaches. Subjective ratings between coaches and their swimmers by cross-assessment was carried out, and coaches also assessed themselves. The mean scores of objective and subjective ratings were compared. A series of pictures of the father-figure were shown and coaches and swimmers answered questions on these. These responses were compared with adult and school-children control groups. Results indicate some similarity between subjective and objective ratings. The father figure seems to have no real significance in the coaching situation.

Hendry, L. B. (1969). A personality study of highly successful and "ideal" swimming coaches. Research Quarterly, 40, (2), 299-304.

Forty-eight selected coaches and 30 international-caliber junior swimmers (under 16 yrs. of age) constructed their "ideal" coach's personality profile on a ten-point scale (from Cattell's 16 P.F.I.). these profiles were compared with the objective test profiles of highly successful coaches and with the coach's self-assessments of personality. Results indicate that greatest similarities were found between coach's subjective self assessments and the "ideal" coach; and between coach's and swimmers estimation of the "ideal" coach.

Hendry, L. B., & Whiting, H. T. (1968). Social and psychological trends in national caliber junior swimmers. Journal of Sports Medicine and Physical Fitness, 8, (4), 198-203.

Factual information by questionnaire technique and additional subjective information by face-to-face interview was obtained from two different groups of 30 (15 males, 15 females) top-class junior swimmers in 1964 and 1967. Attention is drawn to differences which exist within the two groups and the social and psychological implications are discussed.

Houseworth, S. (1984). Comparison of motive to succeed, motive to avoid failure and fear of success levels between male and female intercollegiate swimmers. AAHPERD, Abstracts of Research Papers, 1, 3.

The purpose of this study was to assess and compare the level of motive to succeed, motive to avoid failure and fear of success for male and female swimmers. Subjects were 121 intercollegiate swimmers from major NCAA division I and II teams. Mehrabian's scale, Martens sport competition anxiety test and Peppo's fear of success inventory were used. Analysis revealed elevated levels of motive to succeed, average to low levels of fear of success and motive to avoid failure. No sex differences were seen.

Krahenbuhl, G. S., Plummer, R. F., & Gaintner, G. L. (1975). Motor and sensory set effects on grab-start times of champion female swimmers. Research Quarterly, 46, (4), 441-446.

This study tested the prediction that enforced motor set results in longer reaction, movement, and response times than does enforced sensory set. Fourteen members of a national championship womens team performed the grab-start under each of the experimental conditions. Data supported the prediction being tested for response time. Reduction in response time under the sensory set condition was due primarily to shortened movement time.

Kruger, R. (1971). Correlation between personality and speed. Swimming Technique, 8, (2), 63-64.

This study was to examine the relationship between the speed of competitive swimmers and their personalities. Eighteen varsity swimmers were given the Edwards personal preference schedule and scores were compared with their highest place in a championship swimming meet. Aggression was found to be negatively related to speed and affiliation and nurturance were found to be positively related to speed.

Lampman, J. J., Zauner, C. W., & Pennypacker, H. S. (1968). Anxiety and its effect on the performance of competitive swimmers. Swimming Technique, 4, 119-121.

This study examined the effects of anxiety on competition by swimmers to determine if championship level swimmers respond to anxiety differently than do non-champions. Fifteen varsity swimmers were given the IPAT - 8

parallel form anxiety test battery to evaluate anxiety. Although intense anxiety may interfere with performance, an increase in anxiety from the non-competitor situation appears to facilitate swimming performance. Champion and non-champion swimmers do not differ significantly in regard to anxiety level and performance. Individuals showing low anxiey in the non-competitive situation may perform best if their pre-meet anxiety is also relatively low. Individuals who are highly anxious in the non-competitive situation perform better if their pre-meet anxiety is relatively high.

Matheney, J. R. (1974). Personality traits of male college swimmers. Swimming Technique, 11, 8-11.

This study was to compare the personality traits of outstanding and less outstanding male college swimmers and a control group. Catell's sixteen personality factor questionnaire was used as the testing intrument. The total sample of swimmers were not significantly different from males of similar age in the normal population. The outstanding male swimmers did not differ significantly from the less outstanding swimmers.

McKenzie, T. L. (1972). Effects of various reinforcing contingencies on behaviors in a competitive swimming environment. Unpublished master's thesis, Dalhousie University.

This study was to determine the effects of the application of operant psychology techniques in a swimming environment. It involved three experiments aimed at solving the problems of controlling attendance, work rates, and inappropriate behavior of 20 swimmers in a competitive environment. A problem solving approach using the rules of contingency management was employed. Attendance and work rates were increased and inappropriate behaviors were surpressed.

McKenzie, T. L., & Rushall, B. S. (1974). Effects of self-recording on attendance and performance in a competitive swimming training environment. Journal of Applied Behavior Analysis, 7, (2), 199-206.

Two experiments were conducted in this study. A multiple baseline design varified the effects of publically marking attendance at practice as a solution for reducing absenteeism, tardiness, and leaving early on 16 male and 16 female competitive swimmers. In the second experiment, a reversal design was used to assess the effects of employing program boards as a means of increasing work output during practice on 8 selected swimmers. Work rates were elevated by an average of 27%.

McKenzie, T. L., & Rushall, B. S. (1980). Controlling inappropriate behaviors in a competitive swimming environment. Education and Treatment of Children, 3, 205-216.

A self-recording technique increased the nature and frequency of statements made by the target coach. A second procedure was the playing of a behavior game.

Both conditions decreased the total occurence of inappropriate behaviors, the game being more effective. Repeated baseline conditions showed higher rates of occurence of behaviors than in experimental conditions, but the rates were much less than in pre-experimental conditions.

McNamee, P., & Selder, D. J. (1984). The use of the test of attentional and interpersonal style as a predictor of intercollegiate swimming performance. AAHPERD, Abstracts of Research Papers, 1, 4.

The purpose of this study was to investigate the ability of the test of attentional and interpersonal style to predict performance of college swimmers. Twenty-seven male and female volunteer college swimmers were measured on the test and on swimming performance. Results of the analysis showed no sex differences, order of test taking or response-set instructions. Results did not support predictions on the profile of a superior athlete.

Misner, J. C. (1973). The effect of competition upon the swimming performance of high-, medium-, and low-anxious subjects. Unpublished doctoral dissertation, University of Utah.

To determine the effects of 2 competitive conditions upon the performance of groups of high-, medium-, and low-anxious subjects in sprint and distance freestyle events a group of 54 male high school competitive swimmers were classified into 1 of these 3 groups on the basis of scores achieved on the Taylor manifest anxiety scale. All subjects performed a 50 yd. and a 200 yd. swim under two competitive conditions. Competition with self and competition with others using the front crawl only. Competition with others tended to facilitate persons in a distance swimming performance to a greater extent than in a sprint swimming performance, regardless of anxiety level. The interaction of anxiety and competition was a resultant of the distance swum. The low-anxious and the medium-anxious subjects tended to improve their performances when involved in competition with others and increased distance swum. The high anxious subjects were likely not to have improved, or have had performance decrement.

Newman, E. N. (1968). Personality traits of faster and slower competitive swimmers. Research Quarterly, 39, (4), 1049-1053.

Comparisons were made between actual dual meet times and personality traits as measured by the Thurstone temperament schedule. Twenty-one swimmers were timed throughout the season for each event and the rank of each swimmer calculated. At the .05 level, the dominant trait was positively correlated with 100 yd. freestyle. Negative correlations were found with the social trait and the 100 yd. breastroke and with the reflective trait and 200 yd. freestyle.

Noble, B. J., & Allen, J. G. (1984). Perceived exertion in swimming. Swimming

Technique, 21, (1), 11-15.

Two psychophysical techniques were used to provide data about perceptions: Estimation and production. The production experiment with trained and untrained swimmers indicated that absolute produced effort is significantly higher than requested effort, the effort to initiate swimming may be as high as 50% of maximum and that swimmers produce effort in an accurate and predictable way; and produced effort is significantly higher in trained swimmers. The estimation experiment showed that ratings of effort during swimming respond in the same quantitative way as in land exercise.

Oyster, N., & Arrasmith, J. (1975). Personality traits. Swimming Technique, 12, (3), 89-91.

It was the purpose of this study to investigate possible personality differences among women competitive swimmers, non-competitive synchronized swimmers, and women not competing in any sport activity. Form A of the Cattell sixteen personality factor inventory was given to 89 women. Results indicate that the coach of female competitive swimmers should be prepared to work with individuals who are aloof, cold, jealous, and suspicious. They are independent and aggressive, pursuing their goals in a dominating and emotionally mature fashion. They have about average intelligence and average in superego strength, spontaneity, imagination, sentimentality, self-concept, and tension.

Parsons, D. R. (1963). Personality traits of national representative swimmers - Canada 1962. Unpublished master's thesis, University of British Columbia.

Thirty-five swimmers divided into two groups of selected and non-selected champion swimmers were given the sixteen personality factor questionnaire. The swimmers differed in fifteen of the sixteen personality areas from the general population. No significant differences found between the groups of selected and non-selected champion swimmers. Between male and female swimmers differences existed in dominance, emotion and stability, sensitivity and in both convention and conservative factors.

Rogers, D. D. (1978). Study of the relationship between certain measures of swimming achievement, fear, motor ability, and rhythm among college women. Unpublished manuscript, State University of Iowa.

Rushall, B. S. (1970). An investigation of the relationship between personality variables and performance catagories in swimmers. International Journal of Sport Psychology, 1, 93-104.

Three-hundred and thirty-eight male and female competitive swimmers were grouped in performance and maturational catagories and assessed on the sixteen personality factor questionnaire. A multiple analysis strategy was used to

compare the groups to investigate the consistency of findings across a variety of statistical procedures. Three hypotheses were contemplated concerning the relationship of personality and physical performance classifications. No support for these hypotheses was evidenced in the data. Personality did appear to be partly related to sex of a swimmer. Certain traits were evident in the majority of the groups.

Rushall, B. S., & Leet, D. (1979). The prediction of swimming performance in competition from behavioral information. Canadian Journal of Applied Sport Sciences, 4, 158-159.

The swimming performance of the Canadian team at the 1976 Olympics were categorized as being improved or worse than previous best times in their events. The two groups had previously been assessed. An analysis of that inventory revealed that 13 test questions produced a perfect discrimination of the groups. This was then applied to the test responses of 157 swimmers at the 1977 Canadian Nationals. Using the same performance classification criteria the accuracy of prediction was not better than chance in three of the four sex by performance classifications. This yielded a failure to locate a set of behavioral factors which determine swimming performance improvements in this elite competitive circumstance.

Rushall, B. S., & Pettinger, J. (1969). An evaluation of the effect of various reinforcers used as motivators in swimming. Research Quarterly, 40, (3), 540-545.

Three kinds of rewards were contrasted as to their effect upon swimming work volume. Extrinsic reinforcers of candy and money significantly improved performance over coach's attention and a control condition. The effects of these rewards were differentially affected by age.

Rushall, B. S., & Smith, K. C. (1979). The modification of the quality and quantity of behavior catagories in a swimming coach. Journal of Sports Psychology, 1, 138-150.

Experimental procedures were implemented in a competitive swimming training situation in order to change the repertoire, quality and quantity of several behavior categories in a coach. Self recording techniques were instituted for rewarding, providing feedback, and providing feedback after first having rewarded a swimmer. The repertoire of behaviors in these categories was increased. Pre- and postexperimental behavior analyses indicated that the affected changes produced concomitant changes in other behavioral categories.

Shockley, J. M., Jr., & Gabrielsen, B. W. (1972). Performance analysis at the 1971 NCAA's. Swimming Technique, 8, 110-116.

Participants in the NCAA championships are dominated by freshmen and sophmores. Participants were of average height and weight. One half the swimmers swam slower in the preliminary heats than their official seeded time. Most of the 12 finalists swam faster than their seed time. Most champions

swam faster in the finals than in seeded and prelininary times. Conditioning and tapering practices and warm-up procedures varied among participants with equal success. There was a difference in the ranks of the top teams when ranked by average cumulative percentage, and points scored in the meet.

Van Rossen, D. P. (1968). The effects of diversions on repetitive swimming performance. Unpublished doctoral dissertation, University of Illinois.

To determine if various diversions during training would disinhibit inhibitions and improve both training and competitive performance, varsity swimmers were divided into 2 groups of 10 each on mean 100 yd. swimming times. Diversions were jazz music, jelly bean reward system, no report, word association and memorization. The slight improvement in organic fitness provided an insufficient basis for explaining the improved performance found. Appreciably better training and competitive performances apparently resulted from the disinhibiting effect of the diversions. Diversions during training followed by a return to normal training regimen, apparently had a cumulative beneficial effect.

Vogler, W., & Mood, D. P. (1983). Management of misbehavior in competitive swim practice. AAHPERD, Abstracts of Research Papers, 1, 82.

The purpose of this study was to demonstrate the effectiveness of a group oriented peer behavioral contingency in managing misbehaviors in a competitive swim practice setting. Ninety-five competitive swimmers from 6 to 18 were grouped. Target behaviors were defined and observed over 27 days. The results followed an expected trend. Middle and older groups who related more favorably to their peers responded positively to treatment. Younger groups of swimmers who related more favorably to adults did not respond positively to treatment. It was concluded that contingency behavioral management programs are indicated for children in competitive swimming programs, but not for those below a certain age level.

Welsh, R. L. (1962). Transfer of training in the scissor and frog kick. Unpublished master's thesis, University of Illinois.

This study was to compare the relative effectiveness of teaching the frog kick before and after the scissors kick. Two classes of 19 beginner swimmers were used to compare the two teaching progressions. The frog and scissor kicks were equally good as a means of propulsion for swimmers at the level tested. Scores favored the scissor kick slightly, but the differences were not significant. In general, if one expected both strokes to be mastered, progressing from the frog to the scissor kick seemed preferable.

Bochner, A. (1965). Some medical aspects of swimming. Swimming World, 6, 4-5.

Chapman, A. S. (1953). Effect of water friction upon the eyes of swimmers using a pool treated with high-free chlorine residual. Unpublished master's thesis,

This study dealt with the effect of water friction on eyes of swimmers in a pool containing a high-free chlorine residual. The results indicate that friction of water on eyes is a factor in irritation. This study on 12 females and bacteriological tests on the swimming pool give evidence that a pool maintained with a high-free chlorine residual is satisfactory.

Dominguez, R. H. (1978). Shoulder pain in age group swimmers. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 105-109). Baltimore: University Park Press.

This study sought to determine the incidence of shoulder pain in age group swimmers in the United States. One-hundred and forty-four swimmers were examined for shoulder pain. Shoulder pain appears to be a significant problem for the competitive swimmer. This two year study indicates that in the 13-18 age group, over 50% of swimmers will have some complaints of pain. More than 10% will have shoulder pain significant to the degree that it will cause them to miss practice or swimming meets.

Dominguez, R. H. (1980). Shoulder pain in swimmers. The Physician and Sportsmedicine, 8, 27-42.

Drygus, W., Jegier, A., & Runski, H. (1982). Some medical aspects of training top-class swimmer. Abstract of the 22nd World Congress on Sports Medicine, Vienna.

French, R. W. (1984). Effects of a swimming program on children with cystic fibrosis. AAHPERD, Abstracts of Research Papers, 70.

The purpose of this study was to determine the effects of a swimming program of progressive duration and intensity on the pulmonary function, exercise tolerance, and clinical status of 23 subjects with cystic fibrosis. Compared with a non-exercising control group, the experimental group showed an increase in exercise tolerance, increase in maximal heart rate following training. The clinical status also improved significantly. Pulmonary function of neither group changed.

Greipp, J. F. (1985). Swimmer's shoulder: The influence of flexibility and weight training. The Physician and Sportsmedicine, 13, 92-105. Portions reprinted (1985). Swimming Technique, 22, (3), 17-22.

A test for shoulder flexibility was performed on 168 swimmers, most with no shoulder pain. Six mo. later they reported incidence of shoulder pain during the season. Data showed a correlation between anterior shoulder inflexibility and subsequent shoulder pain. Further study revealed that weight training increased the probability of shoulder pain in males, probably from tendon hypertrophy. The incidence of shoulder pain did not depend on stroke, distance or sex, with one exception. At a given level of flexibility, fly swimmers showed a greater incidence of shoulder pain than others.

Hellebrandt, F. A. (1981-1982). Swimming and its hazards - review of recent medical literature of aquatic guides. Aquatic Guide, 58-65.

Hild, M. H. (1960). Upper respiratory infections among swimmers and modern dancers. Unpublished master's thesis, University of Colorado.

This study was to compare the percentage of students enrolled in swimming classes with one or more upper respiratory infections with the percentage of students in modern dance classes who had one or more upper respiratory infections. Forty-five dancers and 190 swimmers participated. The results indicated that students participating in swimming during the winter months in a heated, outdoor pool do not suffer a significantly greater percentage of upper respiratory infections than do those participating in modern dance.

Hitschler, W. J. (1949). Relationship of swimming and diving to sinusitis and hearing loss. Laryngo, 59, 799-819.

To determine the relationship of swimming and diving to sinusitis and hearing loss. A survey was conducted among 900 college graduates, roughly half of who were trained swimmers. Other information was obtained from correspondance and interviews with swim coaches, school and college personnel, and specialists. The incidence of sinusitus and hearing loss among healthy adult trained swimmers was no greater than among unselected college graduates. There was less severe upper respiratory infection among the swimmers and divers than among the control group. Lesions contracted from swimming and diving were more apt to be severe than those contacted from other causes. Geographical location bore no relation to the incidence of disease. Coaches and swimming experts saw little infection, school and college physicians and boarding school personnel saw more and the specialists the most.

Humphrey, A., & Perinden, W. (1948). Effect of the regular use of the swimming pool during the winter months on the frequency and severity of cold infections. Research Quarterly, 19, 40-42.

Approximately 300 boys, free of factors such as sinus trouble chronic nasal or throat infections, or a high rate of absences or illnes due to cold infections were divided into three groups. The first group of 80 from 11th and 12th grades were excused from activity for the rest of the study. The second group of 80 from the same grades were in gym classes but did no swimming. The third group of the same number were enrolled in regular swim classes. The boys in these classes averaged fewer colds than the other groups. The average duration of infections was shorter for the boys in swim and gym classes than for boys not engaged in activity. The boys in swim and gym classes were not absent from school because of colds as frequently as the group not in physical activity.

Jenkins, B. (1961). Treatment of otitis externa and swimmers ear. Journal of the American Medical Association, 175, 402-404.

A new bactericidal and fungicidal system was presented in the treatment of otitis externa. Without the use of antibiotics or steroids, the new preparation (VosoL Otic) gave excellent results in 200 consecutive cases.

Lane, R. (1955). Investigation of medical opinion on the use of nose clips in swimming and diving. Unpublished master's thesis, University of Southern California.

Lanoue, F. (1950). Some facts on swimming cramps. Research Quarterly, 21, 153-157.

Questionnare data and observations on 1400 students in a swimming program. Frequency, degree of disability, muscles involved, prevention and correction, air and water temperatures, influence of body build and swimming ability were noted. It was concluded that cramps occur in the calf; amount of fat, swimming ability, minor temperature changes or closeness to meals have no bearing on development of cramps.

Livingstone, A. (1932). A study of the effects of inter-collegiate swimming on the sinuses. Research Quarterly, 3, 145-151.

A questionaire about sinusitis was sent to 425 former collegiate swimmers. Of the 206 that replied, 37% were affected with sinusitis. There was an increase of 25% of sinus infection during the period of activity and about 50% of these with sinus trouble stated that swimming was the cause.

Martin, F. E., Jr. (1958). Methods of eliminating eye irritants. Swimming

Pool Age, 32, 86-87.

Not an experimental study, but an excellent summary of what causes and methods of eliminating eye irritants from swimming pools.

Maxwell, J. H. (1941). Some experiences with sinusitis in swimmers. Arch Otol, 34, 797-808.

Data from 13 patients who had been admitted to the hospital with acute fulminating sinusitis after swimming were cited and analyzed. It is proposed that the cause of acute fulminating sinusitis after swimming is the introduction of virulent organisms into a normal sinus which is unprotected and has not had the advantage of forming any local barriers to the infectious process.

Meyers, B. A. (1963). Investigation of the effects of bromine on swimmer eye comfort. Unpublished master's thesis, Smith College.

This study was to determine the use of a bromine compound in pool disinfection in terms of swimmer eye comfort. Four groups of 50 female swimmers were used. After swimming for a period of time each swimmer recorded the degree of eye irritation. In terms of eye comfort the compound was found an efficient pool disinfectant producing a minimum of immediate reaction. In terms of swimmer eye comfort and ease of maintenance bromine was superior to either chlorine or iodine.

Mutoh, Y. (1978). Low back pain in butterfliers. In B. Eriksson & B. Furberg (Eds.), Swimming Medicine IV (pp. 115-123). Baltimore: University Park Press.

The purpose of this study was to investigate the nature of low back pain in competitive swimmers, especially in butterfliers, who seemed to be most affected because of the mechanical stress on their lumbar spines. Five female and 48 male well trained Japanese competitive swimmers were investigated. Radiological surveys made it clear that the butterfly stroke occationally caused increases in lumbar lordosis accompanied by spondylolysis and/or degeneration of intervertebral disc giving rise to low back pain.

Rahe, R. H., & Arthur, R. J. (1975). Swim performance decrement over middle life. Medicine and Science in Sports, 7, 53.

Richardson, W. (1952). Swimmers muscle cramps. New England Journal of Medicine, 247, 811.

Ruhling, R. O., Foster, J. C., Latin, R. W., & Johnson, S. C. (1983).

Cardiorespiratory and metabolic responses to pregnancy, jogging and swimming. Abstracts of Research Papers of AAHPERD, 29.

The purpose of this study was to compare the physiological effects of jogging through pregnancy to swimming through pregnancy. Same subject studied through two pregnancies, one jogging only and the second both jogging and swimming. Data suggest that no apparent adverse effects occur to either mother or infant during pregnancy from either method of maintaining aerobic fitness levels.

Staton, W. M. (1952). Swimming as an etiological factor in the incidence of certain otorhinologic conditions in college men. Research Quarterly, 23, 98-105.

A cross sectional experiment was conducted to determine the influence of aquatic activity in development of certain otorhinologic pathologies. The subjects, a homogeneous group of male college students, followed the same regimen except for the experimental variable of swimming and water sports activity. The swim group of 109 participated in aquatics in an outdoor fresh water pool twice a wk. for one hour per session. The non-swim group of 85 did not have swim activity during the 60 day experiment. Subjects were asked to report to the university infirmary if they experienced any of the signs of ear, nose, throat, or sinus infection. It was concluded that participation in swimming and water sports does not result in a significant increase of infections. Resistance to ear,nose,throat, or sinus infection, including acute coryza, is not altered by engaging in aquatic activity. From the standpoint of student health, swimming is not contraindicated for the college physical education program. Sixty references.

Struhl, T. R. (1957). Medical aspects of swimming. The 18th Annual WAF Report, 32-34, & (1959). The 20th Annual WAF Report, 35-36.

Thomas, C. L. (1963). Medical aspects of swimming. The 24th Annual WAF Report, 23-31.

Wiley, V. G. (1939). Investigation of causative relationship of swimming and diving to sinus and head infections. Unpublished master's thesis, University of Southern California.

This study was to collect from literature and authoritive opinions data about the hygiene of swimming pools and bathing beaches. An effort was made to determine, with the hygienic measures of bathing areas, the extent to which sinus, eye, ear, nose, and throat infection still prevailed. Sixteen conclusions and 12 recommendations about bathing were given.